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NEW 32-BIT CMOS MICROPROCESSORS.

The two new members of NEC's CMOS microprocessor V-Series bring unprecedented density and performance in the 32-bit realm. The V60 and V70 supermicros are the first to integrate a Memory Management Unit and basic floating-point processing functions on a single chip.

The V60 has a 16-bit external data bus for an easy, affordable path into 32-bit products while the V70 is a full 32-bit engine designed to power leading-edge systems.

The super-fast V60 and V70 offer a clock speed of 16MHz, and execute 3.5 MIPS and 6 MIPS respectively. A six-stage pipelined CPU enables concurrent execution of up to 4 instructions. With 32 on-board 32-bit general-purpose registers, there is no need to access slow off-chip memory.

The V60/V70 feature an on-chip memory management unit with 4 gigabytes of demand-paged virtual memory space, and 4 levels of memory protection for multi-tasking and multi-user environments.

The V60/V70 instruction set is ideal for high-level languages and OS support (UNIX™ V and proprietary realtime OS). There are 21 addressing modes, 273 instructions, and an emulation mode for 16-bit V20/V30 software.

UNIX: trademark of AT&T Bell Laboratories.

NUMBER 136

COMING SOON: 1.3/1.55μ DFB LASER DIODES.

Dispersion has always been a major obstacle in long-distance, high-speed lightwave communications. With conventional laser diodes emitting multiple spectrums, pulses deteriorate by dispersion after long travel through the fiber. This in turn limits repeater span to 20–30km and capacity to 400–560Mbps for the prevalent 1.3μ fiber optic systems.

NEC has overcome this obstacle with newly-developed distributed feedback (DFB) laser diodes for 1.3μ and 1.55μ fiber optic transmission systems. They feature a stable single longitudinal mode operation, high efficiency and high output power. The new DFB laser diodes are expected to expand repeater span to 80–100km for 1.3μ system or 100–200km for 1.55μ system.

NEC's new DFB laser diodes inherit the renowned double channel planar-buried heterostructure (DC-PBH) and have a diffraction grating in the optical guide region to produce a single wavelength. Output powers are rated 8mw for the 1.3μ NDL5600 and 5mw for the 1.55μ NDL5650. They come in the TO-5 package with an integral monitor photo diode or chip-on-carrier configurations.

As matching light-receiving devices, NEC has planar type InGaAs avalanche photo diodes. They have a selective guard ring construction to achieve high sensitivity and excellent reliability.

NEW INTELLIGENT BUILDING COMPLEX AT VANCOUVER.

The intelligent building is an idea whose time has come. As the perfect nestling for office workers in the Information Age, it centers on an advanced information management system which provides simultaneous voice, data and image services to tenants at less cost while it controls the entire building environment efficiently.

The World Trade Centre/Pan-Pacific Vancouver Hotel recently opened is just such an installation. NEC's NEAX 2400 Information Management System (IMS) allows tenants to utilize enhanced telephone/facsimile services including least-cost routing, message center and voice mail services, and computer terminal connection via a multifunction digital telephone set. The NEAX 2400 IMS also offers sophisticated services to hotel guests.

NEC's Intelligent Building Systems, based on our unique C&C (integrated computer and communications) technology, are the most advanced and comprehensive available today. As the core of this system, the modular NEAX 2400 IMS can expand to 255 tenant partitions. It supports more than a hundred advanced features including a protocol converter to allow communication with most popular host computers.

NEC also supplies comprehensive component equipment including multifunction digital telephones, information display pagers, high-speed facsimiles, business and personal computers, teleconferencing and CATV equipment and local distribution microwave links.

NEC's comprehensive systems breathe new life into the smart building concept, bringing costly services like teleconferencing within the reach of every business.

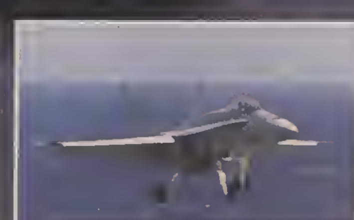
NEW HIGH-CAPACITY 64QAM DMR SERIES.

NEC's newest 800 Series high-capacity digital microwave radio (DMR) systems transmit two or three DS3 signals per RF carrier, utilizing 64-state quadrature amplitude modulation (64QAM) for effective use of radio spectrum.

Three systems meeting FCC standards are available: a 4GHz 90M-bit system providing 1,344 voice channels, and 6GHz and 11GHz 135M-bit systems for 2,016 voice channels.

The new systems incorporate the latest LSIs, hybrid and microwave ICs throughout to achieve compact design, lower power consumption and improved system reliability. Housed in a standard 19-inch rack, they require minimal cabling work for installation.

The advanced 800 Series is fully compatible with Bell's facility maintenance and administration system.



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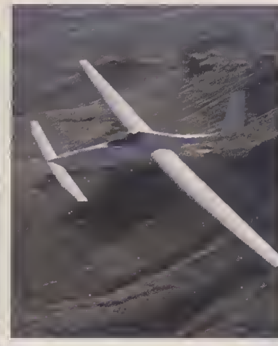

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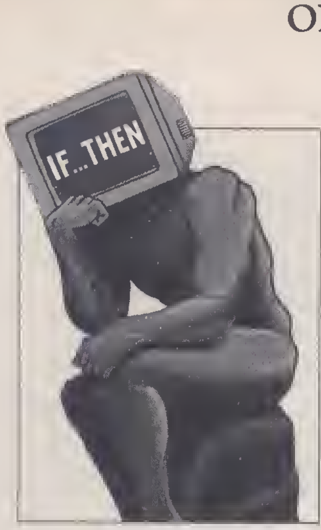
FEATURES

DEPARTMENTS

Cover A guided vehicle transfers computer disks being assembled at Magnetic Peripherals (Minneapolis). Photograph by Steve Niedorf.

OPINION



ROD THOMAS

Artificial intelligence has a bad name

Technological buzzwords sometimes take on meanings of their own, often far removed from real technology. Artificial intelligence, or AI, is a good example. An image has been created of computers that think like human brains.

Some skeptics, taking this implied definition at face value, charge that such machines are not merely beyond today's technology but impossible to achieve at all. (Maybe so, although history tells us that "experts" frequently show that something can't work just before it does.) Meanwhile, philosophers struggle to draw the line between machines that are or are not "intelligent," and the notion persists that intelligent machines may become malevolent monsters, like HAL in *2001*. Of more immediate concern are fire-and-forget missiles that might turn on the ships that launch them, shoot down passenger planes by mistake, or trigger a war.

Semanticists urge care in the use of language. Names and the images they evoke can color our perceptions and even affect important policy decisions. Since AI is "hot," vendors grab onto the label, hoping to land military contracts, orders from major companies, or venture capital. But creating inflated expectations will eventually backfire. Consultants advised a large insurance company, for instance, to develop an expert system to help top executives create completely new kinds of insurance. Prudently, IBM advised the firm not to try to apply the technology to situations where there was no past experience. Instead, a more realistic proposal was made for a system that would check the writing of thousands of standard policies to see if they followed well-defined procedures.

Misconceptions may come from using a term like "expert system," which could imply a machine able to solve novel problems in imaginitive ways. Typically, what's programmed into such systems is the ability to follow the various rules of thumb that enable very experienced professionals to quickly solve fairly routine problems. Some vendors now call them "knowledge-based" systems, in fact, to avoid such confusion.

This emerging technology isn't magic; it's just a different approach to programming computers. Some intelligence is already incorporated in conventional software, but its power is constrained by the rigid sequential nature of traditional programming. And although AI has much to offer business, industry, and the military, it too has limits. No one can build systems to write symphonies à la Beethoven or to design aerospace planes. But because AI software is faster and more powerful, it could help specialists work more efficiently, enabling them to creatively explore many more options.

Learning more about human thinking may help improve our technology, but the debates about machines that think like humans should remain with the science-fiction writers. It's time to burst the overblown expectations and put this technology to work where it makes sense.

Robert Haavind

Robert Haavind

high Technology

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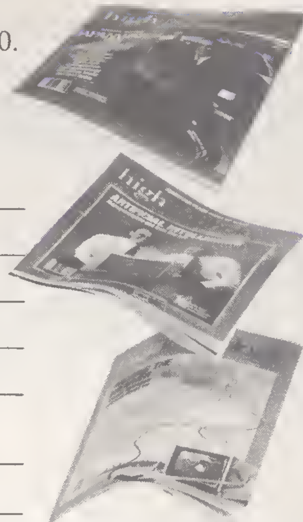

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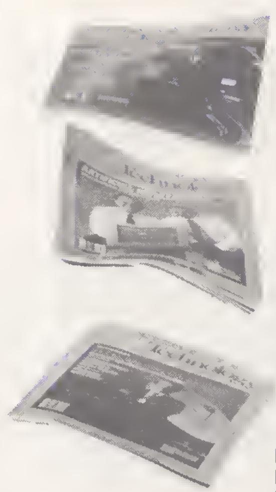

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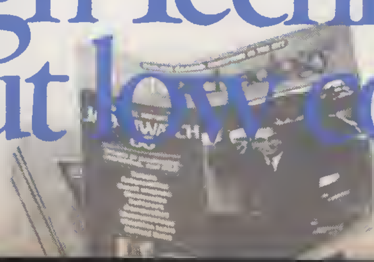

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LETTERS

Synergy in America

"Software: Tools for compatibility" in "Japanwatch '86" (Aug. 1986, p. 34) appears to suggest that the Japanese will excel in computer technology because of unified goals and national funding—and that because of the alleged absence of such national programs in the United States, we will fall behind both in the technology and the marketplace.

I disagree. Research efforts similar to Japan's Sigma project exist in the U.S., and many of them, such as MIT's project Athena, Carnegie-Mellon's workstation project, and the National Science Foundation's supercomputer project, were expressly designed to be cooperative.

Other cooperative efforts in the U.S. have developed through the open exchange of ideas—for example, over national computer networks such as Arpanet, Bitnet, and CSnet. Even networks like USEnet and FIDOnet, without defined objectives or central administration, connect programmers for the purpose of sharing information. The point is that cooperation builds in America not from nationally organized efforts but by individuals from the ground up.

Just because our development is not completely paid for with government funds, and our programming style does not follow Japan's methodology, does not mean that advances are not being achieved.

Mark R. Scherfling, Supervisor
DEC, Networking, and PC Support
Computer Center, GTE Laboratories
Waltham, Mass.

A failure to telecommunicate

Your Special Report on telecommunications (May 1986, p. 21) neglected one key element: its role in local economic development.

Japanese local officials are hard at work in developing local information systems to serve the needs of citizens and businesses in regional economies, but such a strategy is virtually ignored in the U.S.

A few American cities—such as Cambridge and Palo Alto—have started building local networks for data communications and information services, but they are doing so with their cable systems, not the phone system.

David Lytel, Alderman
Common Council
Ithaca, N.Y.

We welcome comments from our readers. Please address letters to Editor, High Technology, 38 Commercial Wharf, Boston, MA 02110. Or send to MCI Mailbox: HIGHTECHLET.

ILLUSTRATION BY MICHAEL BLASER

Good idea, bad image

I enjoyed your article "Pulling together on computer communications" (Sept. 1986, p. 30). However, your use of an eight-man shell to represent teamwork hit a technical problem. While rowing (particularly in an eight-man shell) is one of the best and most complex team efforts you could have used, the boat as pictured—with eight sweep oars on one side—will only go in circles (to the left). More likely, the boat will roll over. That is perhaps why the coxswain has chosen to remain ashore.

I'm sure that is not the image you wanted to project, but it did not detract from the article.

Charles A. Smith
Nashville Rowing Club
Nashville, Tenn.

We'd like to point out that the chart illustrating the variety of international standards in your article on the Corporation for Open Systems was produced by Retix Corporation in Santa Monica, Cal., not Sytek.

Edward Cooper
Director of Business Development
Sytek
Mountain View, Cal.

Quick fixes miss the point

I've been reading your Opinion pieces about Far Eastern competition, and the concepts you outline have struck a chord.

I am an electrical engineer and design products for commercial and consumer telecommunications. I work at a West Coast company that manufactures a line of related products that must be individually tested and manually aligned. At one time last year, our factory turned out 20,000 units per month, and approximately 30 minutes was devoted to testing each unit.

Pressured by mounting financial losses, management recently targeted labor as the primary means for cost reduction and decided that offshore manufacturing was the answer. But a better way to cut the product cost would have been to reduce the *amount* of labor—by developing a unit that does not require any tuning.

U.S. manufacturers wouldn't need to immediately go offshore if they devoted the proper engineering resources up front. Foreign vendors and manufacturers can actually be used effectively by U.S. companies, but they should not become some all-purpose fix for problems closer to home.

(Name withheld by request)

Quoth the maven: "Livermore"

We were pleased and flattered by your reference to the precision machining capabilities at "Lawrence Livermore Laboratories in Berkeley, Cal." in "Japanwatch '86" (Aug. 1986, p. 50). However, the late E.O. Lawrence founded *two* laboratories, known as the Lawrence Livermore National Laboratory and the Lawrence Berkeley National Laboratory, respectively located some 40 miles apart in Livermore, Cal., and Berkeley, Cal.

Ray McClure, Leader
Precision Engineering Program
Lawrence Livermore National Laboratory
Livermore, Cal.

Canada first?

"Tilt-rotor aircraft rise to the occasion" (Aug. 1986, p. 67) made no mention of the Canadair CL-84 Dynavert designed and built in Montreal in 1965. There is a rather striking similarity between the CL-84 and the V-22 Osprey. Yet another result of the continuing brain drain from Canada to the U.S.?

Hugh A. MacLean
Oakville, Ontario

The caption to the following photograph from "Videoconferencing expands its horizons" (Sept. 1986, p. 59) was incorrect. It should have read: *Pratt and Whitney Canada's videoconferencing system, based on Colorado Video's freeze-frame equipment, can simultaneously display meeting participants as well as objects under discussion.*

PRATT & WHITNEY CANADA

UPDATE

Graphics conference on videotape

In a new twist on the saying "the show must go on," Frost & Sullivan (New York) is selling an encapsulated version of the computer graphics industry's leading exposition on a 90-minute videocassette. Aimed at graphics vendors and users, the tape identifies market trends and surveys some 60 products introduced at Siggraph '86 last August in Dallas. It also includes interviews with industry authorities at the show and commentary from Frost & Sullivan's analysts.

The market research firm claims that the $395 tape provides many of the benefits of attending Siggraph, but at a fraction of the cost. Laurin Herr, the videotape project leader and president of consulting firm Pacific Interface, says that "video is the ideal medium for a report about Siggraph, because so much of this conference is intrinsically visual." Still, Frost & Sullivan sees the tape as only the first in a series that will cover major conferences in other industries as well.

Lab safety comes under federal scrutiny

A proposal from the Occupational Safety and Health Administration seeks to establish toxic-substances guidelines for laboratory chemists, who until now have been largely exempt from OSHA surveillance. If passed into law next year as expected, the regulations could mean brisk new marketing opportunities for manufacturers of laboratory safety equipment, according to Carl R. Brewer, marketing manager for Foxboro, a lab instrumentation supplier in South Norwalk, Conn. At the same time, many small research firms might find themselves hard pressed to comply.

The agency's approach is uncharacteristically flexible: instead of imposing rigid laboratory rules on chemical executives and researchers, OSHA would require each company to develop a written plan detailing its worker protection measures—how it will monitor atmospheric toxics, dispose of hazardous wastes, and so on. By and large, the proposal has the blessings of the chemical industry and most of its professional groups, including the American Chemical Society.

The measure presents little threat to large companies with well-established safety programs. But many smaller firms would have to dramatically upgrade their employee training programs and equipment—such as hoods and ambient-air monitoring devices—or face heavy penalties. "A lot of them are still unaware of even basic employee safety rules," says Wayne Bickerstaff, industrial hygiene manager at Westinghouse in Pittsburgh.

Landing gear for rocky runways

Can large airplanes be equipped to operate from makeshift, pockmarked, or battle-scarred runways? An Air Force study under way at Boeing Military Airplane Co. (Seattle) seeks to identify temporary devices that can be strapped onto C-130 cargo craft to give them extra mobility on the ground, enabling them to taxi, take off, and land in any weather on runways strewn with boulders and foot-deep ditches.

Engineers will consider four major technologies, according to Randall Brown, laboratory program manager for the project at the U.S. Air Force's Aeronautical Systems Division at Wright-Patterson AFB in Ohio. Extra wheels could be connected to extended axles or to a platform mounted on the landing gear or fuselage; low-friction skis or skids could be attached to the landing gear or airplane structure; caterpillar tracks could be slipped over the landing

Air cushions could enable Air Force C-130 cargo planes to land on rough terrain.

wheels, with the nose wheel modified to accept skis or skids; or a hovercraft-like air cushion device could be strapped onto the entire underside of the aircraft.

Boeing will prepare a preliminary design of the system it deems best, on the basis of such factors as overall efficiency, installation time, and effects on aircraft speed and payload capacity. The study won't be devoted entirely to the C-130; it will also consider rough-terrain landing gear for the much larger C-17 transport plane.

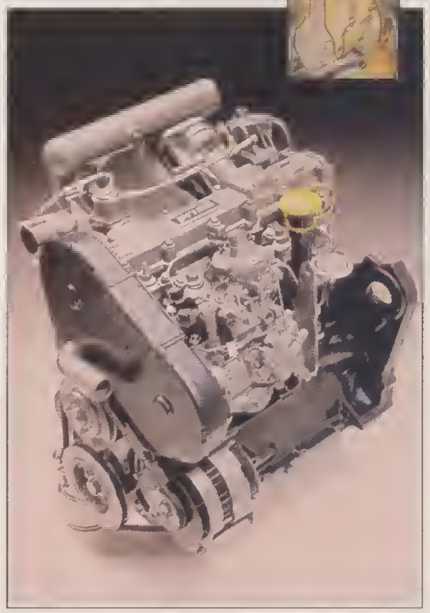
Dick Tracy, phone home

Status-conscious people on the go may soon be tempted to give up their conspicuous pocket beepers for the convenience of a paging device miniaturized into a digital watch. The Receptor, an FM receiver/timekeeper being developed by AT&E Corp. (San Francisco), will be able to display short messages, such as "call home" or the phone number of a caller. Someone wishing to call a Receptor wearer will phone AT&E, which will relay the message to a network of FM radio stations across the country. The stations will digitally encode it onto a subcarrier by using a combination of frequency and phase modulation that doesn't affect the main signal.

Key to the wristwatch pager are two application-specific integrated circuits developed by Britain's Plessey Semiconductor. One IC is a complete FM receiver (normally, a receiver comprises several chips). The other is a frequency scanner that lets the receiver step automatically through the entire FM broadcast band looking for a 32-bit address code that announces an incoming message. The two chips occupy a combined space just 0.25 inch square by 0.08 inch deep and run on a conventional watch battery.

AT&E—which intends to subcontract the manufacture of Receptor pagers, possibly to Japan's Seiko—expects to have the devices on the market late next year.

Perkins's fuel-efficient diesel. Inset shows contoured air-intake ports (yellow, above valve heads) and indentations on piston heads, which promote fuel/air mixing.



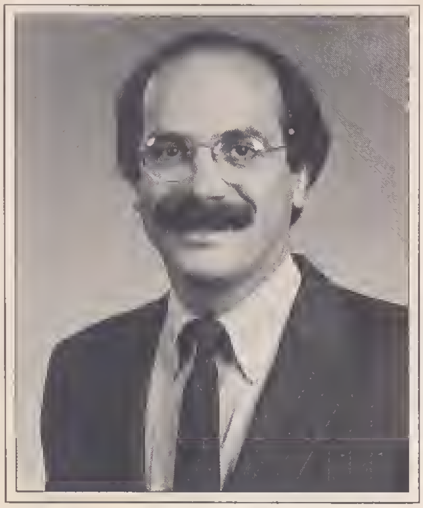
Fuel-saving diesel

A new diesel engine for automobiles delivers about 15% better fuel economy than existing small diesels, or some 40% higher efficiency than gasoline-powered engines, claims developer Perkins Engines (Peterborough, England). Unlike other car diesels, the two-liter, four-cylinder Prima engine injects fuel into each cylinder directly—as in some heavy-duty truck engines—rather than by way of a "prechamber" adjoining the combustion chamber.

In a diesel engine, fuel and air trapped in each cylinder's combustion chamber must mix thoroughly for efficient burning, which occurs spontaneously when the piston compresses the mixture enough to raise its temperature to the fuel's flash point. But for a small diesel to produce enough horsepower, it must be able to run at high speeds (above 4000 rpm) that leave little time for adequate fuel/air mixing. The fuel in conventional car diesels is therefore squirted first into a small prechamber—where combustion begins, forcing the fuel through a narrow inlet into the main chamber. This method amplifies the movement of the fuel, but it squanders energy, since heat generated in the prechamber escapes through the surrounding metal instead of helping to move the piston.

In the Prima engine, Perkins replaces the prechamber with more efficient ways of mixing fuel and air: incoming air passes through helical ports, causing it to swirl as it enters the combustion chamber; multi-hole injection nozzles atomize the incoming fuel; and indented regions on the piston head create turbulence as the piston compresses the fuel and air.

The engine will be manufactured jointly by Perkins and Austin Rover Group (initially for the '87 Austin Maestro van) at a starting rate of about 80,000 units a year. Perkins currently has no plans to sell the engine in the U.S., where the diesel engine market for cars and light trucks is stagnant.



A better way to design products

David Kelley
President, David Kelley Design

In the current environment of intense international competition, a company lives or dies by its ability to develop quality products quickly and efficiently. But the product development process in most companies is in great need of improvement.

Traditionally, the development process is performed by a series of specialists who work with the product in sequence, passing it from one function to the next. Each functional group—marketing, engineering, manufacturing, sales, and others—makes its major contributions to the product only once, and there is little dialogue between them. This serial approach does not result in the most intelligent design trade-offs, and it catches major problems later rather than sooner.

For example, when manufacturing's involvement comes at the end of the product development cycle—as it typically does—problems must often be retraced through the entire process, a costly and time-consuming practice. But if the problems were caught earlier, corrections would be simpler and less expensive, and the products could reach market sooner.

A different approach to product development—I call it the parallel approach—must be embraced. It begins by bringing together everyone responsible for any aspect of the project at the beginning, in the same room, to cooperate on the development strategy, and it stresses their continued interaction throughout the process.

Having design engineering, manufacturing engineering, marketing, service, quality control, production, and even a sampling of vendors and customers work together accomplishes several things: It helps departments with contradictory goals understand each other's concerns and align with each other's goals, and it brings the individuals responsible for the project closer, ultimately inspiring cooperation. In addition, it generates a larger number and wider diversity of ideas. And bringing in potential vendors and customers allows their concerns to be heard, spawning a loyalty to the final product that is hard to inspire any other way.

Through this process, the design engineer who wants to design something technically interesting can start to understand the constraints of the manufacturing engineer, who must control costs. In the parallel approach, everyone's opinion is heard on every subject because everyone stays with the project from beginning to end.

One company that incorporates aspects of the parallel approach is Apple Computer. In its early days, Steve Jobs would often seek a marketing person's opinion on a product design—a tradition that the company's present management maintains. But in general, several organizational barriers prevent companies from adopting this approach.

For example, functional specialists are rarely encouraged to communicate with other departments. When I was a novice design engineer at Boeing, my boss forbade me to talk to people in manufacturing because he didn't want them to think we didn't already know everything. So I would design products they weren't capable of producing and would have to do everything at least twice. If I could have talked to them up front, I would have learned the facts the first time.

Another barrier is the inherent aversion to risk when functional areas are isolated. I once suggested that a particular Fortune 500 company use infrared technology in a new product. The engineering manager and the marketing manager both loved my idea, but neither would champion it because neither one, by himself, could afford to support a concept that might fail. But if both individuals had been working together, with other specialists included, the risk would have been shared and probably perceived by each individual as small enough to be worth taking.

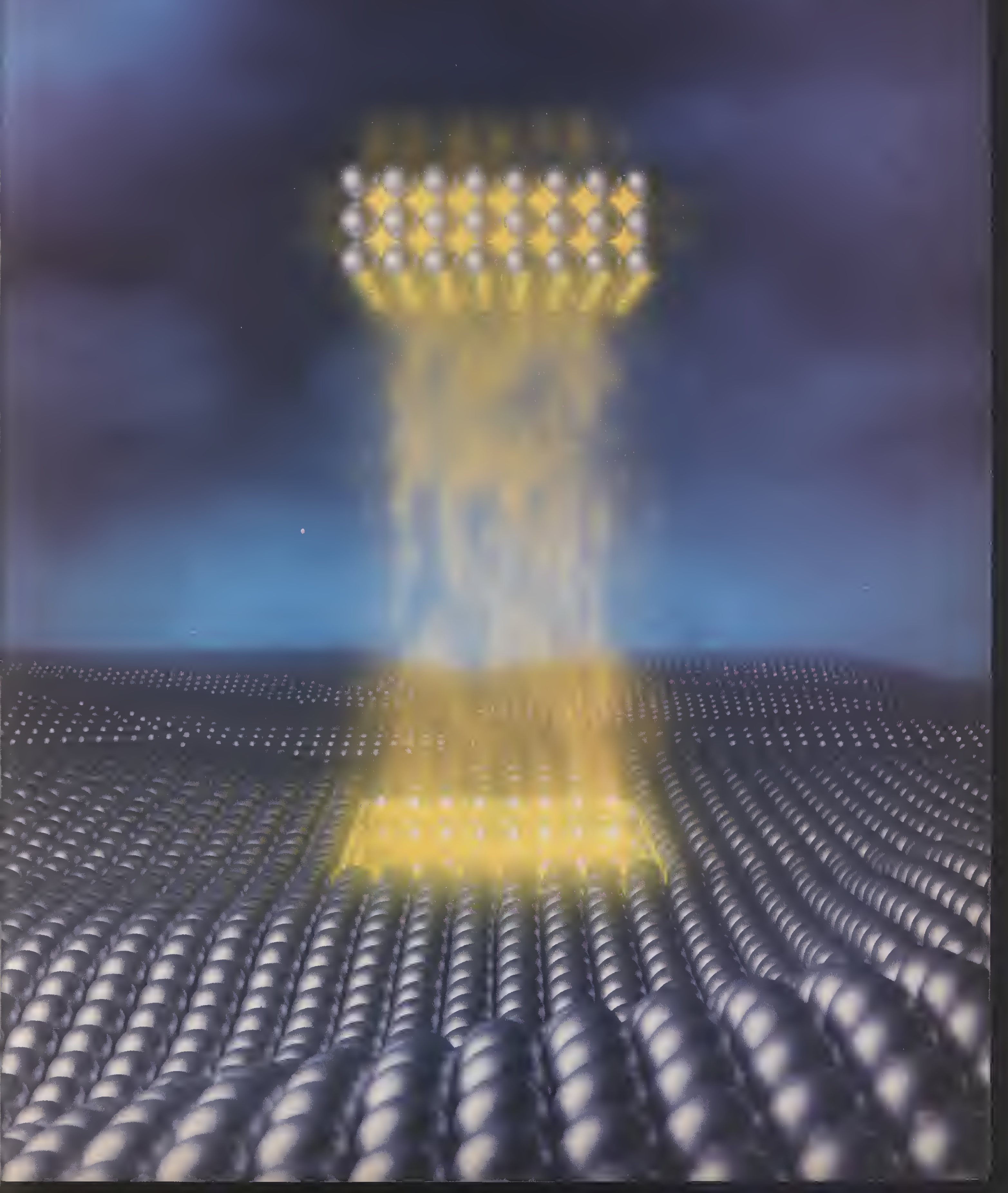
A third barrier is the scarcity of people with a working understanding of product-development disciplines beyond their own. Such people are especially well suited to work with others in making intelligent trade-offs between conflicting design goals, but they are in extremely short supply because of an educational system that rewards specialization.

Once these institutional barriers are overcome, the methodology is critical. Rather than bringing people together only once, the parallel approach should be iterative, with many small and not-so-small design cycles. Having the whole development group make multiple passes not only allows mistakes to be corrected early but enables the group to consider a wider range of possible designs before choosing the best. Because the product reflects the contributions of many specialists—including the end user—its probability of success is greatly increased.

Simply stated, the parallel approach means bringing together a broad range of talent, trying things out, learning from each attempt, and then trying again. It enables more reliable products to be developed in a shorter time, and can thus improve a company's competitive position in the global marketplace. □

David Kelley Design (Palo Alto, Cal.) provides product-design services to a variety of companies.

The Pressure Extrapolation



The Pressure Extrapolation

Modern automotive catalytic converters contain rhodium which promotes chemical reactions to remove pollutants from a car's exhaust. Scientists at the General Motors Research Laboratories have recently made discoveries about one such chemical reaction, the reaction between nitric oxide and carbon monoxide, pointing the way toward new or improved catalysts.

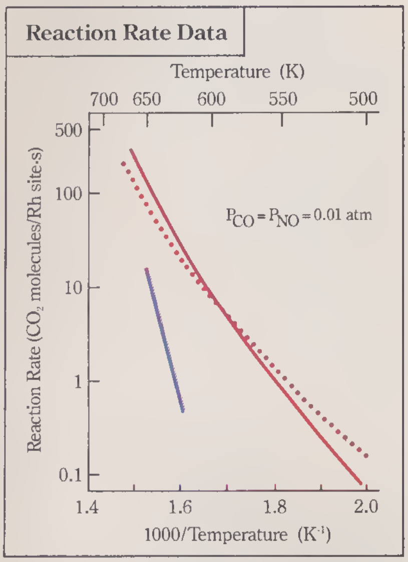
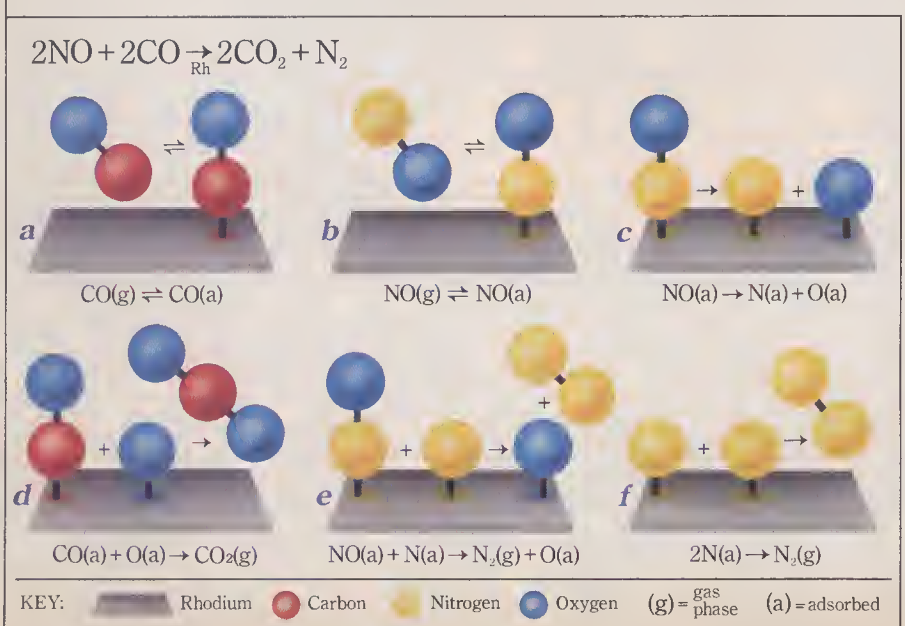


Figure 1: Rate comparisons for the NO-CO reaction. Measured data over single crystal Rh(111) (solid red line) and over supported Rh (blue line); model predictions (dotted red line).

Figure 2: Schematic representation of the elementary intermediate steps for the NO-CO reaction.



MOST FUNDAMENTAL catalytic studies using surface science techniques require an ultrahigh vacuum environment (10^{-13} atm). They are best suited for studying well characterized materials, such as metal single crystals. Catalytic reactions of practical interest, however, involve polycrystalline materials, in the form of small metal particles dispersed on supports. And they take place at atmospheric pressures rather than in an ultrahigh vacuum.

Now Dr. Galen B. Fisher and Dr. Se H. Oh have demonstrated how the wealth of chemical information obtained from ultrahigh vacuum (UHV) studies of ideal, single-crystal catalysts can be applied to the understanding of real-world systems that have different catalyst environments and that operate at much higher pressures.

These researchers concentrated their studies on the many chemical reactions that occur in modern automotive catalytic converters. One such reaction is the reduction of nitric oxide (NO) by carbon monoxide (CO) over a rhodium (Rh) catalyst to yield carbon dioxide (CO_2) and nitrogen (N_2) (Figure 2).

Dr. Fisher used various surface science spectroscopies in ultrahigh vacuum to study all of the elementary reactions over a rhodium single crystal [Rh(111)] that might be involved in this specific reaction. Over several years he measured the rates and determined the activation energies of each of these reactions. For most of these reactions, this was the first time these parameters had been measured. Based upon these results, Dr. Fisher hypothesized that the elementary reactions shown in Figure 2(a-f) were the significant steps involved in the NO-CO reaction and that nitrogen recombination and desorption (Figure 2f) was the rate-controlling step on Rh(111).

Dr. Fisher and Dr. Oh also initiated kinetic studies of this reaction at realistic reactant partial pressures and temperatures using two different catalysts—one was a rhodium single crystal [Rh(111)], and the other consisted of rhodium particles supported on alumina [Rh/Al_2O_3]. The rhodium concentrations on the support were similar to those used in an automotive catalytic converter. The studies with the single crystal at realistic, high pressures were done in collaboration with Dr. D. Wayne Goodman of Sandia National Laboratories.

At the same time, Dr. Oh devised a mathematical model for this reaction. The model consists

of steady-state conservation equations for the surface species, based on the reaction mechanism and the rate expressions for the individual reaction steps determined in Dr. Fisher's UHV studies. Overall reaction rates could then be computed from the surface concentrations satisfying the conservation equations. The reaction rates predicted by this model, which depend only on reactant partial pressures, are shown in Figure 1 (dotted red line).

The kinetics of the NO-CO reaction measured over a rhodium single crystal using realistic reactant partial pressures are shown in Figure 1 (solid red line). The agreement with the model predictions indicates that Drs. Fisher and Oh had correctly identified all of the intermediate reaction steps and confirms that, in this case, nitrogen recombination and desorption (Figure 2f) is the rate-controlling step on Rh(111). The fact that the agreement is so good also indicates that the rates of the elementary reactions measured under UHV conditions are still valid at realistic reactant partial pressures—a pressure extrapolation of more than ten orders of magnitude.

THE KINETICS of the NO-CO reaction measured over the supported rhodium catalyst (Figure 1, blue line), however, were much slower than predicted by the model. In addition, infrared studies have shown that NO is the predominant surface species on the catalyst, suggesting that in this case NO dissociation (Figure 2c) is the rate-controlling step. In fact, if the rate constant for NO dissociation measured under UHV conditions and used in the model is reduced by a factor of 2000, the kinetics of the NO-CO reaction measured over the supported rhodium catalyst are correctly predicted.

The difference between the kinetics of the NO-CO reaction measured over a rhodium single crystal and the kinetics measured over supported rhodium shows that this reaction depends on the environment of the rhodium in the catalyst. The reaction model strongly suggests that the NO dissociation reaction is the reaction step most sensitive to the rhodium environment.

"While our reaction model cannot tell us why NO dissociation is slower on supported rhodium," observes Dr. Oh, "it can help identify the kinds of studies necessary to clarify the origins of such sensitivity." Comparative kinetic studies can also provide useful insights for developing improved NO reduction catalysts. "Our studies have already told us," adds Dr. Fisher, "that one possible path to improving automobile catalysts is to make modifications that increase the NO dissociation rate."

General Motors

THE MEN BEHIND THE WORK

Dr. Galen B. Fisher (left) and Dr. Se H. Oh are both Group Leaders in the Physical Chemistry Department at the General Motors Research Laboratories.

Dr. Fisher holds the title of Senior Staff Research Scientist, and heads the Surface Chemistry and Corrosion Science Group. He attended Pomona College as an undergraduate and received his graduate degrees from Stanford University in Applied Physics. Before coming to General Motors in 1978, he did post-doctoral studies at Brown University and worked at the National Bureau of Standards. Since then, his research has been involved with surface science studies of various catalytic reactions.

Dr. Oh is a Senior Staff Research Engineer, heading the Catalytic Kinetics Group. He received his undergraduate degree from Seoul National University and holds a doctorate in Chemical Engineering from the University of Illinois. Dr. Oh did post-doctoral work at the University of Toronto prior to joining GM in 1976. Since then, he has been involved in measuring and modeling the kinetics of catalytic reactions.

BUSINESS STRATEGIES

Educational Computer:
SIMULATING TANKS AND PLANES

Even with a $300 billion budget, the Pentagon needs to find ways to save money, and one way is by training troops to operate tanks and jet fighters through simulators and computerized mock-ups. "Ten years ago, most training was done on the actual equipment," says George Frye, executive VP of Educational Computer, a leading manufacturer of simulated weaponry. "But now the actual equipment is so expensive that, more and more, training is being done with simulators."

Based in Stafford, Pa., but with most of its operations in Orlando, Fla., Educational Computer makes training equipment for U.S. as well as foreign armed forces. Its sales have tripled in the past five years, resulting in profits of $2.8 million on revenues of $27.8 million for fiscal 1986. "Educational Computer pioneered the field of computer-controlled simulation training systems and continues to hold a commanding industry position," says Philip Leigh, a research analyst with Williams Securities (Tampa). The firm traces its origins to the late 1960s, when a group of engineers left Martin Marietta's Orlando Aerospace operation to form a computer company. After going through several incarnations, it emerged under its current name in 1973.

Today, the company supplies simulators used to train operators and maintenance crews in a variety of weaponry, such as the Army's M1 Abrams tank and the Navy's F-18 Hornet fighter. Last year it was awarded a $16 million contract to produce 3-D replicas of the turrets of the M2 Bradley Fighting Vehicle armored personnel carrier; these simulators will be used at Army training schools in the U.S. and West Germany. The company does virtually all design and manufacturing for these systems, says Frye, subcontracting "almost nothing."

Its most recent plum is a $15 million contract for a videodisc-based system for gunnery training—not unlike a highly sophisticated video arcade game. Awarded through the Naval Training Center, the contract "is quite a feather in the cap of Educational Computer," says Leigh, "and they are expanding pretty rapidly."

Educational Computer's simulators and computerized mock-ups are used to train operators of the Army's M1 tank and the Navy's F-18 Hornet jet fighter.

Simulators are not only a cheaper way to train military personnel, they are also constructed to take more wear and tear than standard-issue vehicles. "In a trainer, we can simulate emergencies," says company VP James Ferguson. "We can have engine failures or cockpit fires." The systems even supply realistic sound effects; pilots using the simulator for the Swiss-made PC-7 aircraft, for example, hear the screech of tires hitting tarmac and the thumps that signal holes in the runway. The simulator for the F-18 is such an exact replica of the real plane's cockpit, boasts Ferguson, that it "does everything but fly."

Increasingly, Educational Computer is emphasizing foreign sales. For instance, its PC-7 simulators are built for the United Arab Emirates. To qualify for bidding on Common Market contracts, it is opening a design and assembly complex south of London. While the company intends initially to focus its efforts there on software development, it plans to build an operation that eventually will be comparable to its facilities in Orlando.

The only cloud on Educational Computer's horizon at the moment is the possibility that a downturn in defense spending might cut programs it is counting on for the future. But cutbacks might also end up working in the company's favor by increasing the Pentagon's reliance on cost-effective simulators. "It is a long-term business, not quarter to quarter," says Frye. "Almost every major weapon system is buying trainers."—***Tim Smart***

American Rocket:
FILLING IN FOR THE SHUTTLE

NASA's recent decision to withdraw the Space Shuttle from deploying commercial satellites is proving to be a boon for at least one segment of the aerospace industry—the makers of privately owned launch vehicles. Formerly excluded from serious consideration by most potential users, this handful of companies is now suddenly in demand.

One of the group's most recent additions is American Rocket (Palo Alto, Cal.), founded in April 1985. It hopes to capture the low-cost end of the market with launches of small payloads that weigh less than two tons and have low earth orbits, says company president George Koopman. These limitations exclude most telecommunications satellites, but the rocket should still be able to deploy many weather, military reconnaisance, and other special-mission satellites. Concentrating on the low end of the market also avoids competing directly with the French Ariane rocket and with expendable U.S. launchers like the Delta and Titan from companies such as Martin Marietta, General Dynamics, and start-ups Transpace Carriers and Space Services. A conglomeration of smaller satellites should provide "sufficient opportunities to accommodate the company's business objectives over the next three years," says James Samuels, managing director for research at McLeod Young Weir, Inc. (New York).


RICK BROWNE

American Rocket president George Koopman with liquid oxygen tanks that will power low-cost launchers designed by his firm.

American Rocket intends to keep down costs by designing its own rocket, rather than leasing an existing design. "Every rocket currently available is a military missile designed with little regard to cost performance," says Koopman. These rockets "are built as if they were race cars," he declares, "while ours will be more like a Dodge van." Current plans call for a simple unmanned four-stage vehicle with a dozen engines on the first stage, four on the second, two on the third, and one on the fourth. Engines on all stages will be nearly identical to keep production costs low in comparison to conventional designs.

In April, the Air Force agreed to allow the company to use its test facilities at the rocket propulsion laboratories at California's Edwards Air Force Base. American Rocket's first engine test took place there in May, and more than 20 additional tests have been run since. The company has also devised scaled-down test procedures to contain costs, with engine firings monitored by just one engineer using several personal computers. "The Air Force officials were pretty surprised by our procedure," recalls Koopman. "They were used to running engine tests with five to ten engineers and putting the data on a mainframe."

American Rocket has been operating on just $1 million raised from private investors, but discussions are under way with Shearson Lehman Brothers and Prudential-Bache about raising an addition $30 million. While the *Challenger* disaster and more recent launch failures undoubtedly helped put American Rocket "in the right business at the right time," says one investor, the Space Shuttle's exit from commercial launches has also created new corporate activity in what had been a sparsely populated market. "The NASA policy decision has created competition for American Rocket," says Samuels. "Companies like Martin Marietta and General Dynamics weren't interested in this market prior to the policy changes." Nonetheless, American Rocket plans to demonstrate a full-size working engine in early 1987 and is scheduling its first flight for 1988. —***Jeffrey K. Manber***

Chiron:
SYNTHETIC VACCINES FOR SALE

Like many biotechnology companies, Chiron (Emeryville, Cal.) has earned most of its revenues performing contract research for large pharmaceutical firms. In particular, Chiron has become "the leader in using recombinant DNA for vaccines," says Jim McCamant, editor of the *Medical Technology Stock Letter* (San Francisco). Last August, the Food and Drug Administration approved the sale of Chiron's synthetic hepatitis B vaccine, the first genetically engineered human vaccine. This product, whose worldwide market is estimated at $200 million by McCamant, has been licensed to Merck (Rahway, N.J.) for manufacturing and distribution.

Conventional vaccines stimulate the body's immune system by exposing it to inactivated live viruses. Although many vaccines have successfully eliminated epidemic diseases around the world, they pose a number of problems, explains Edward Penhoet, Chiron's president. They are derived from limited natural supplies such as blood plasma, and thus are difficult to produce in quantity. In addition, they can potentially cause the disease they are meant to prevent because of the small chance that vaccine-based viruses can remain alive.

Genetically engineered vaccines eliminate most of these problems by removing from the virus only the genes responsible for making the anti-

gen—the part of the virus necessary to spur the immune system into action—and then growing it in harmless host cells such as yeast. The synthetic viral particle looks and acts like a real one in provoking the immune response, but it is completely noninfectious. Thus consumers can feel reassured in using the vaccine, and manufacturers face much less chance of liability suits.

Chiron recently signed an agreement with Ciba-Geigy for joint development and commercialization of a range of other vaccines, including those for herpes, malaria, two other types of hepatitis, and AIDS. Development of an AIDS vaccine could generate a billion-dollar market if the general population is recommended for vaccination. Chiron's scientists have synthesized all the structural proteins that make up the AIDS virus and are now testing different combinations of such proteins in animals to learn which ones stimulate the immune response. Chiron has also developed an effective vaccine for feline leukemia, thus demonstrating the feasibility of making a vaccine against a retrovirus, the same type of virus as AIDS.

Like many other firms in this industry, five-year-old Chiron has yet to make a profit, but revenues rose from \$5.8 million last year to \$7 million in 1986. Penhoet is confident that such growth will continue, because selling technology is only one part of Chiron's current business strategy. It is following two other lines that will help broaden its revenue base beyond royalties derived from contract research.

One path has involved the manufacture of proteins for other companies; these materials serve as the key ingredients in many pharmaceutical products such as insulinlike growth factors (IGFs), hormones that stimulate bone and muscle growth, and superoxide dismutase (SOD), an enzyme that reduces damage after heart attacks and strokes. Chiron's partners for IGF and SOD proteins are Ciba-Geigy and Pharmacia, respectively. The second path involves a recently launched subsidiary, Chiron Ophthalmics, which will develop, manufacture, and market the company's own line of wound-healing products, such as epidermal growth factor, for ophthalmic surgery patients.

"Chiron has put together an outstanding scientific team and has a strong position in several significant product areas," says McCamant. "We regard it as our favorite biotechnology stock."—***Eleanor Smith***

After three decades of relatively quiet existence, automated guided vehicles (AGVs) are suddenly winning the endorsement of leading U.S. manufacturers, as flexibility and adaptability become critical on the factory floor. The AGV industry had only about half a dozen vendors 10 years ago, but now their number has more than quintupled, and new major players like the robot giant GMF Robotics are still entering the business. This heightening competition, plus demands from users for ever-increasing sophistication, is fostering advances in AGV technology. For example, a whole new class of vehicles is being developed that finds its way without any guidepaths.

Automated guided vehicles fit into two broad manufacturing categories. In materials handling, AGVs deliver inventory from holding to production areas, or between workstations; they replace manually operated equipment like forklifts or rigid automation like transfer lines. In assembly systems, AGVs are themselves the production platforms, supporting products like automobiles, engines, and garden tractors while work is performed. Thus they do away with conventional industrial conveyor lines.

GUIDED VEHICLES SET MANUFACTURING IN MOTION

Freewheeling carriers are providing new flexibility in materials handling and assembly

by Jeffrey Zygmont

Industry's adoption of AGVs is analogous to the transportation revolution that occurred when trucks largely replaced freight trains. A train passes each stop in sequence, and facilities served by train must cluster near the rails. But a truck goes wherever there are roads. It doesn't have to pass every stop; it can bypass some and hit others in the order of their priority.

The AGV brings similar flexibility to factories. Although the current generation of driverless transporters still follow mapped routes, they are easily reconfigured to meet changing production needs. And unlike a conveyor line, an AGV can be sent to any station in the system's route, in any sequence, at any time.

The benefits of AGV flexibility will be showcased at GM's operation in Oshawa, Ontario. Currently under renovation, it will house the world's largest concentration of AGVs. Two identical factories making GM midsize W-cars will have about a dozen separate systems, totaling about 1100 individual carriers. Volvo Automated Systems (Sterling Heights, Mich.) is the main vendor, supplying all but the 100 or so AGVs that Conco Tellus (Mendota, Ill.) is outfitting for the paint-shop repair lines. At GM's nearby Oshawa pickup truck plant, Conco Tellus is installing a 424-vehicle AGV system.

In Oshawa's labor-intensive areas, AGV systems permit workpieces to stop at each assembly station for an average of 3½ minutes, allowing workers to perform more involved tasks than they can in the one minute permitted on a moving line. "That has quality implications," says Terry R. Kotwa, senior plant engineer at the car facilities. "It gives a worker more ownership; he can see a bigger chunk going together."

What's more, AGV systems allow a single assembly line to split into several parallel lines where identical operations are performed. Kotwa says this was a key determinant for AGVs at Oshawa. "Parallel processing drastically increases your uptime; if one station goes down, the others still produce," he explains. The flexibility of AGVs permits paralleling much more readily than conveyor systems, which can't be split into multiple lines and remerged later without prodigous hardware additions.

To meet the specialized needs of different industries, AGV carriers may be outfitted with a wide variety of fixtures for holding or transferring workpieces. Some have motorized roller tables, for instance, that transfer parts from atop the carrier to the receiving area of a workstation. And large automobile-body carriers can raise cars several feet off their deck to give workers easy access to the underside.

With most AGV systems—installed by major suppliers like Volvo Automated Systems, Conco Tellus, Eaton-Kenway (Salt Lake City), and Por-

BENNO FRIEDMAN

Volvo's Angiewicz, aboard a carrier in a car-seat assembly line, says AGV systems are growing rapidly because they complement the manufacturing trend toward flexibility.

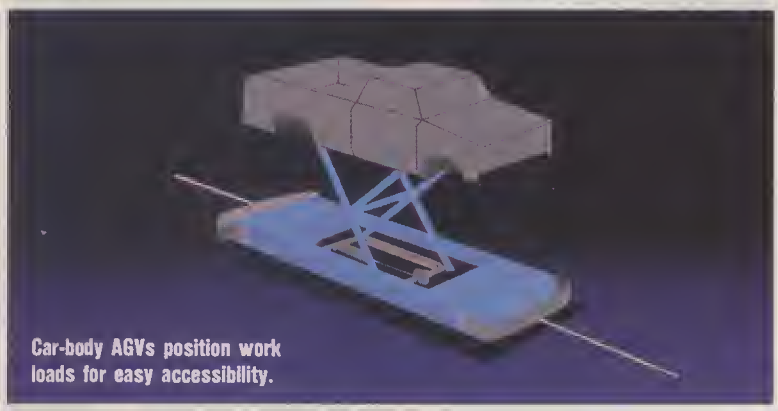
tec (Lisle, Ill.)—guidepaths consist of wires embedded in the factory floor. Each carrier has an antenna that detects the magnetic fields surrounding the guide wires when the wires are energized at low voltages. The antenna generates an output signal corresponding to its location within the guidepath's magnetic field. To keep the antenna (and thus the carrier) centered over the path, a microprocessor on the carrier reads antenna signal strength and adjusts the carrier's steering mechanism to maintain a constant signal.

An alternate guidance method employed by Litton Industrial Automation Systems (Zeeland, Mich.) relies on transparent guidelines painted onto the floor. As a Litton carrier passes over the transparent strip, fluorescent particles in the guidepath are energized by an ultraviolet light beneath the vehicle. A photosensor detects the energized guidepath, feeding the on-board microprocessor the signal it needs to control steering. A big advantage is that the lines can be applied to any surface, even carpeting, says Litton; embedded wires generally require a concrete floor. However, the strip needs periodic reapplication, especially in high-traffic areas, where it wears more quickly.

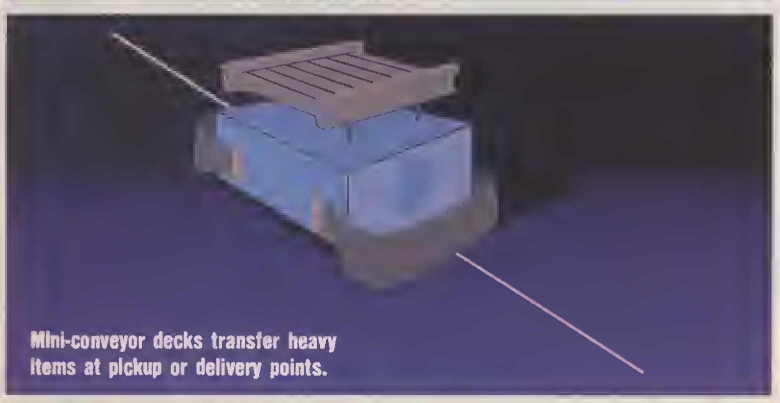
In all but the simplest AGV systems, a central control computer dispatches carriers, tracks them, and governs their movements on the various guidepath loops. Communications networks, usually dedicated wiring in the floor, permit the transmission of encoded messages like status reports from carriers or commands from the controllers. Large AGV systems often use a control hierarchy that divides the total system into zones, each with a lower-level controller that reports to the central computer and

GETTING JOBS DONE

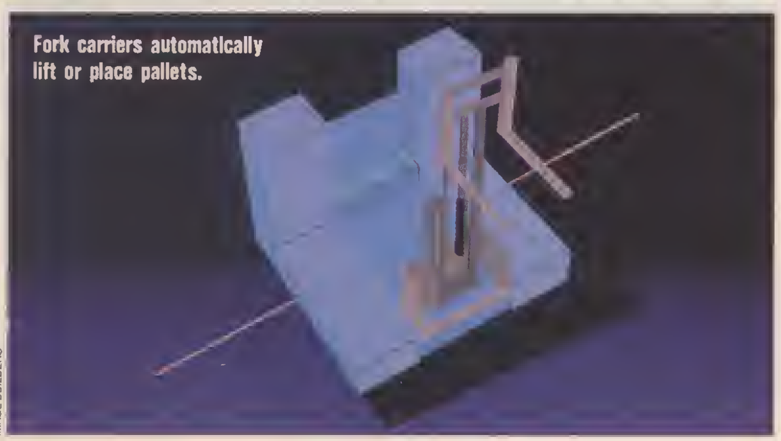
Robot-equipped carriers load and unload themselves.



Car-body AGVs position work loads for easy accessibility.



Mini-conveyor decks transfer heavy items at pickup or delivery points.



Fork carriers automatically lift or place pallets.

IMAGE BUILDERS

the frequencies of the alternating current in each loop. Since each loop is energized at a different ac frequency, carriers stay on the correct path—rather than wandering onto another one at intersections within their zone—by following a designated frequency.

Since AGVs are electrically powered, recharging is another important control priority. In some cases, carriers are temporarily removed from the system and sent to recharging areas, where they plug themselves in. Less disruptive, however, is "opportunity charging," carried out when a vehicle is in use. If a vehicle will be stopping at a specific station for a long enough span, the central computer instructs the carrier to engage the automatic charging terminal at that station. With Volvo systems, for example, a carrier parks over receptacles embedded in the floor at workstations. When instructed, it lowers its charging arm, which engages the receptacle and absorbs the charge into its battery power system. Thus the carrier receives many short boosts during the production period, keeping its batteries at least 80% charged.

The AGV concept was first applied on a large scale to manufacturing in 1974, when Volvo (the automaker) installed a 260-carrier system at its plant in Kalmar, Sweden. Since then the AGV population has grown to more than 15,000 vehicles, making up about 3300 systems worldwide. President Clifford T. Anglewicz of Volvo Automated Systems claims industry sales will grow to $1 billion by the early 1990s, from current levels of below $200 million. Most of the growth will take place in assembly AGV systems, since they are so large, according to a report being prepared by Norman W. Jetta for the New York consulting firm Frost & Sullivan. At three Oshawa plants alone, GM is installing assembly AGV systems that will employ about 1500 carriers.

Because they require so many carriers per system, automobile plants are the largest users of AGVs. But that market is being shaken by GMF Robotics' purchase last spring of wire-guided AGV technology from Eaton-Kenway, a subsidiary of Eaton Corp. (Cleveland). Under the agreement, Kenway will continue to serve the AGV needs of its existing customer base, but GMF gains the right to manufacture the vehicles and sell them under the GMF name to automakers and other industrial segments. Already the world's largest robot maker, GMF is half owned by General Motors, which is expected to give the Troy, Mich., company a large portion of GM's future AGV business.

That will hurt other guided vehicle suppliers, since GM is their largest single customer by a wide margin. To regain sales that may be lost in the automotive sector, major AGV suppliers are launching marketing campaigns to introduce the AGV concept to other industries. Volvo, for instance, which currently claims to have 25–30% of the U.S. market (thanks to the recent sale of some large automobile assembly systems), is now approaching light appliance companies. Volvo also plans a major marketing push in materials handling, having concentrat-

ed until now on assembly systems. And Portec, the company that supplied large AGV systems for automobile engine and chassis assembly to GM's Flint, Mich., plant, is targeting the printing and papermaking industries, and plans to sell more systems for transporting workpieces between stations in flexible manufacturing systems, says AGV marketing manager Michael Dempsey.

AGVs have already found an eager market in the electronics industry, where small carriers with motorized receiving and unloading devices transport in-process inventory. At NCR's Wichita, Kans., plant, for example, two Litton carriers shuttle printed circuit boards between storage and assembly areas, providing flexibility to meet changes in production demands among the plant's three products: computer data storage devices, business minicomputers, and minis for bank and retail transactions. "If you put in any kind of hard automation like an overhead conveyor, it's there for good and you have to work around it," says Peter Sommerville, plant automation engineer.

NCR's system is relatively simple as AGV installations go: there is no host computer; instead, the two carriers have keypads for the manual entry of destination codes before each run. Sommerville reports that even this modest system has yielded a significant reduction in inventory. (Since delivery time is faster, fewer parts are needed to fill the pipeline between storage and production areas.) Also, the simplicity of the system allowed it to be integrated smoothly into the Wichita facility; guidepaths were installed in a weekend, workers trained in a day.

At Magnetic Peripherals, the Minneapolis manufacturer of hard disk drives, Litton optically guided carriers are used in a cleanroom, where special flooring rules out embedded wires. "We've made a multitude of changes in our assembly process, and the system has been able to accommodate them in a matter of minutes," says Rick Heupel, manager of module production for the Large Disk Division. Now the company is exploring the use of AGVs as cleanroom assembly platforms for manual workstations. (So far, electronics manufacturers have used AGVs largely for material transfer.)

The promise of such expanded applications is driving significant new developments in automated guided vehicles. GMF's longer-term strategy is to merge AGV's with robots, says vice-president Jimmy L. Haugen. Carriers with robot arms that load and unload themselves eliminate the need for separate machines or laborers at each stop where parts must be transferred. Gerald D. Michael, manager of Arthur D. Little's Manufacturing Automation Technologies Unit in Cambridge, Mass., expects to see more ventures between robotic and AGV suppliers like that between GMF and Eaton-Kenway.

Hybrids of AGVs and robots are already on the market. Automation vendor Flexible Manufacturing Systems of Los Gatos, Cal., has sold four of its Mobile Transport Units, consisting of an AGV coupled with a six-axis robot from Intelledex (Corvallis, Ore). Although it claims

STAYING ON COURSE

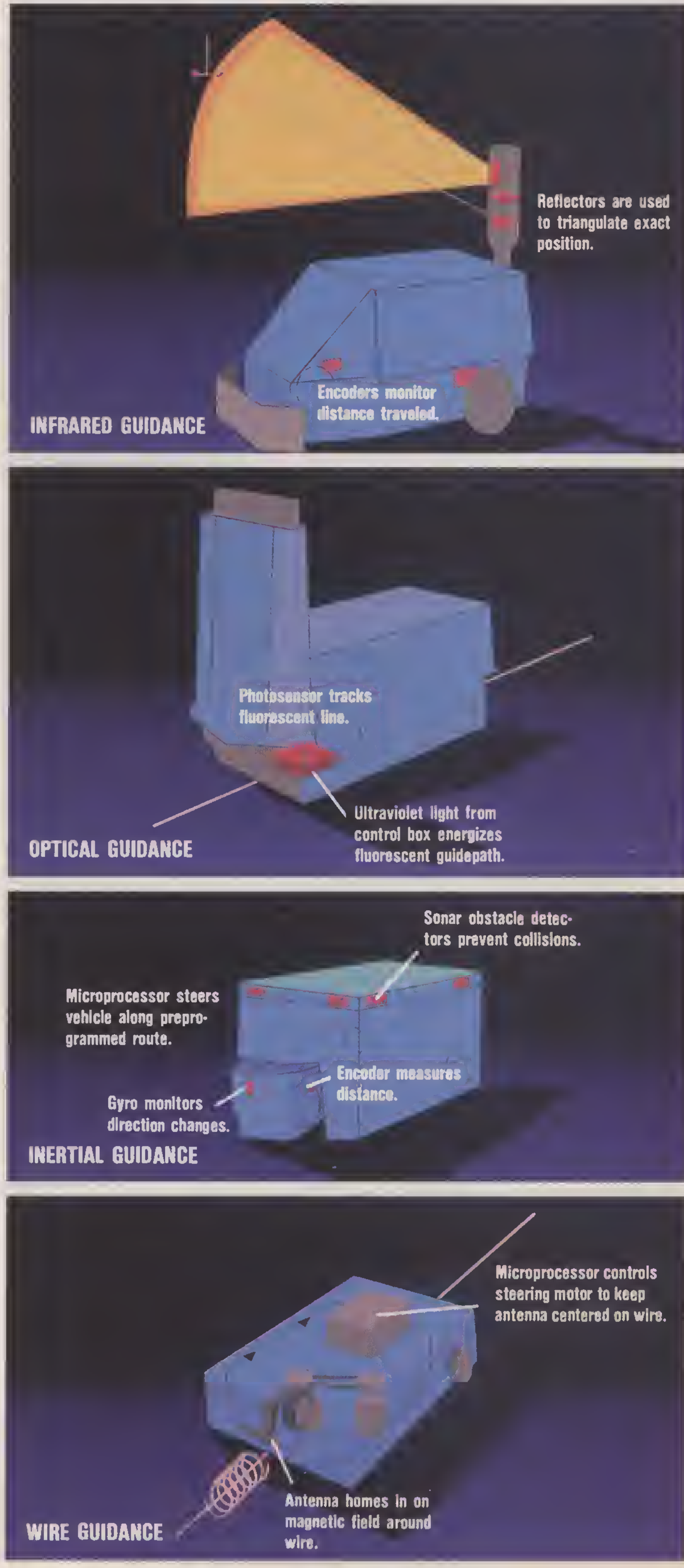


IMAGE BUILDERS

"Industrial robotics and industrial AGVs are merging," says ADL's Gerald Michael, although extensive use is three to seven years away.

facturing Systems of Los Gatos, Cal., has sold four of its Mobile Transport Units, consisting of an AGV coupled with a six-axis robot from Intelledex (Corvallis, Ore). Although it claims that adaptations for other industries are coming, Flexible Manufacturing so far has targeted electronics companies, pitching its Mobile Transport Unit to microchip makers as part of a computer-integrated manufacturing concept. The carrier is specially designed to transfer silicon wafer cassettes or other cleanroom containers between workstations. It is dispatched and controlled by a central computer that communicates with the carrier via an infrared signal system. According to independent tests conducted for the company, wafers transferred by the robot carrier have one-tenth to one-third the particle contaminants of manually handled wafers.

Positioning accuracy has been a nagging technological hurdle to affixing robots to AGVs: the robot must be in the exact same floor position each time it arrives at a station if it is to accurately carry out its programmed task. Flexible Manufacturing solves this problem with an optical docking method that automatically compensates for minute deviations in carrier position. As the vehicle approaches a station, a laser on its front illuminates a one-inch strip of mirror attached to the dock. Photosensors, also on the front of the carrier, detect the reflection from the mirror's two outside edges, yielding the angle between the center line of the carrier and the edges of the mirror. With these data, the AGV's on-board microprocessor computes the deviation of its center line from its intended position and makes appropriate adjustments.

But the coming wave of AGV technology is self-navigating carriers. "There's a big incentive to eliminate those guide wires," says Arthur D. Little's Michael. Laying guide wire is disruptive and costly, and some surfaces, like the wood-block floors of older factories or the floors of machine shops where metal chips accumulate, don't accommodate embedded wires.

Already, some wire-guided systems have limited off-wire capabilities. For instance, the Conco Tellus Tele Carrier system permits off-wire repetition of maneuvers performed on-wire. Carrier wheels are equipped with encoders that store routine distances in the carrier's computer memory. Then, if a carrier is traveling down an aisle and turning right at, say, 12-foot intervals to service pickup-and-delivery zones that are five feet off the aisle, the host computer can instruct the vehicle to repeat the maneuver at the end of the guidepath instead of turning to follow its loop. Off-wire capabilites can reduce system costs substantially when a large number of pickup-and-delivery spurs off the main guidpath are needed, says Portec's Michael Dempsey. For instance, a Portec system for a food-processing plant in the southeastern U.S. has about 1000 off-wire points. "Otherwise we would have had to cut spurs to 1000 stands," says Dempsey.

AGV systems that communicate via in-floor wiring lose touch with carriers that leave the guidepath. However, Barry Timmerman, AGV marketing manager for Conco Tellus, says that the company's system maintains constant contact by radio. To avoid signal interference, he says, data are transmitted over a special FCC-licensed band that is free of other commercial broadcasts and high enough to be isolated from the electromagnetic interference given off by production equipment. The low-power (2-watt) system is largely confined within factory walls.

But wire-guided AGVs can't stray more than about 20 feet from their guidepaths, says Timmerman. Any farther and the carrier's encoder could be fooled by such things as wheel slippage, which could result in an inaccurate distance reading.

The coming wave of autonomous AGV systems will likely compensate for such navigation errors with external reference points for navigation assistance. Flexible Manufacturing, which was the first company on the market with an autonomous carrier, uses each dock as a reference point: after a carrier calculates its docking error with the aid of Flexible's optical method, it computes the minute steering corrections needed to get it back to its true path once it leaves the dock. That path to various workstations, and around obstacles, is taught by an operator who walks it through the route. The carrier actually stores several routes in its memory, and can retrace any of them when instructed by the central host computer.

Caterpillar Industrial, the Mentor, Ohio, subsidiary of the construction equipment giant Caterpillar Tractor, is testing its inertially guided AGV system in its parent's Aurora, Ill., plant, where wood-block floors prohibit wire-guided systems. The AGVs check their positions with infrared laser scanners that read bar-code labels affixed to reference points throughout the factory. Stored in AGV memory are the position coordinates of each reference label, so a carrier's control computer is able to determine its position by triangulation based on the labels within its field of view.

Another approach is the infrared guidance system developed by The TOR Group (Saint Laurent, Quebec) and applied to its own trailer-towing AGV. Atop a mast on the TOR-VEE carrier is an infrared beacon that rapidly sweeps a vertical beam of light back and forth ahead of it. Reflectors suspended from the factory ceiling at regular (usually 25-foot) intervals above every aisle bounce return signals to an optical array in the mast. TOR-VEE navigates by scanning for and following a preprogrammed sequence of reflectors. In its computer memory is the position of the next reflector along its planned route; thus the carrier scans only where it expects to find that reflector, ignoring others that are not in the proper position. Once it's locked onto its target, the carrier can more precisely calculate its distance from that reflector, pinpointing its position within the factory.

Since TOR's database contains a "roadmap" of all the reflectors within the factory, new routes can be made on the fly. A new sequence of reflectors is programmed into a control comput-

er and downloaded via the system's infrared optical communication link. (Research at TOR aims to develop artificial intelligence for carrier navigation that will permit a vehicle to select its own route, once a destination is entered.) One drawback to infrared communications, however, is that it requires line-of-sight positioning between carrier and data transmitter; commands must wait until TOR-VEE crosses a designated communication point.

The TOR-VEE system is being well received by manufacturers who can't use wire guidance, according to David M. Osborne, manager of TOR's U.S. operations, in Farmington Hills, Mich. In one plant, a TOR system crosses a steel drawbridge over a sunken railroad track; in another, metal tailings on the floor around presses would interfere with wire guidance. "A lot of times the reason we get jobs is because there isn't any other way to do it," Osborne says. Also, for long distances the installed cost of $1 per foot of travel for TOR's reflector system compares favorably with the $8–$10-per-foot cost for wire guidepath installation, he says.

But in AGV assembly systems, the guidepath is only a small percentage of total system cost. Carriers, used in such large numbers, represent the highest cost. And in individual price per carrier, wire-guided vehicles have an advantage over self-navigating ones, which require more sophisticated sensing and computing power (and are still in an emerging stage).

What's more, self-navigating automated guided vehicles provide more flexibility than is usually needed in an assembly operation, where, once laid out, AGV routes are not likely to change, since the massive workstation equipment they service can't be moved and rearranged anyway.

Therefore industry analysts and AGV vendors alike expect wire-guided systems to continue to dominate the AGV assembly-system market. However, in materials-handling applications—a market considered less mature—the added flexibility of self-navigating systems has a bigger payoff. Storage and retrieval areas, for instance, often have a large number of possible routes that can be costly and difficult to reach by wire. And because materials-handling systems generally require far fewer carriers than assembly systems do, cost per carrier is less a factor.

Moreover, while the market for assembly AGV systems is hot today, it will reach a saturation point, predicts Arthur D. Little's Michael, since only a limited number of products are suitable for AGV assembly. Anything much larger than a car, he says, is unmanageable for carriers. And when products are much smaller—like toasters or dishwashers—their value is often too little to justify the additional expense of AGV assembly systems over a simple, light-duty conveyor. When this saturation point is reached, says Michael, the market for driverless materials-handling carriers in warehousing, fabrication, and even offices should have matured enough to pick up the lost momentum of assembly systems.

EDDIE SHVARTZMAN

By reducing human handling, the self-navigating, self-loading robot AGV of Flexible Manufacturing Systems greatly lessens cleanroom contamination.

Thus, many suppliers of automated guided vehicles are setting future sights on material transfer applications. Says Volvo president Anglewicz, whose company is beginning its first forays into materials handling, "That market is a tremendous opportunity." □

Jeffrey Zygmont is a senior editor of HIGH TECHNOLOGY.

For further information see **RESOURCES**, *p. 68.*

RISING STARS IN CONSUMER ELECTRONICS

by Herb Brody

Look for new wrinkles—not revolutionary products—from the folks who brought us videocassette recorders, compact disc players, and camcorders. While those items remain extremely popular (and well covered in the media), some of the biggest consumer-electronics advances are embodied in products that have been overshadowed by the star performers. These items range in size from hand-held remote control units and pocket televisions to entire homes. Most are on the market now; a few, such as digital audio tape and the "Smart House," are not. Some seem assured of commercial success; stereo television sets, for example, stand poised to assume dominance, much as color TVs have pushed out black-and-white. There are also chancier ideas, such as the notion that the public will support a new wave of home video games.

Prices are manufacturers' suggested retail unless otherwise noted. Happy shopping.

TV: Stay tuned for better sound and picture

Television has always looked a lot better than it sounded. While sophisticated hi-fi systems sprouted in millions of living rooms, TV sound remained comparatively crude. But as more and more sets come equipped with circuitry to decode the stereo audio that now accompanies many network broadcasts, sound quality is starting to improve.

Most high-end sets now come equipped with MTS (multichannel television sound) decoders and two or four speakers, adding depth to TV's traditionally thin sound. Zenith Electronics (Glenview, Ill.), which developed the MTS standard, currently equips more than half its product line with stereo; such sets are expected to account for more than 20% of the company's 1986 TV sales.

Stereo broadcasting now has a status analogous to color transmissions during the 1960s, when NBC displayed a special symbol—the unfurling peacock—before each color program. The peacock lost its significance once color became routine on the airwaves; now the network runs a message alerting viewers that an upcoming show is in stereo. Equipment for stereo broadcasting has now been installed at some 300 local TV stations, which Zenith estimates can reach 87% of the U.S. population.

Not that stereo alone assures high-quality sound. In many cases, stereo TV means basically that sound trickles out of two three-inch speakers instead of one—and speakers that small generally produce substandard sound. One common solution is to hook the TV up to a hi-fi audio system, routing the signal through the larger and higher-quality speakers. One drawback to this approach is that many TV buyers don't want to bother with such a hookup; they merely want to plug the set in and watch it. Moreover, physically separating the sound from the picture can be disconcerting. (For this reason, most of the sound in movie theaters comes from speakers directly behind the screen.).

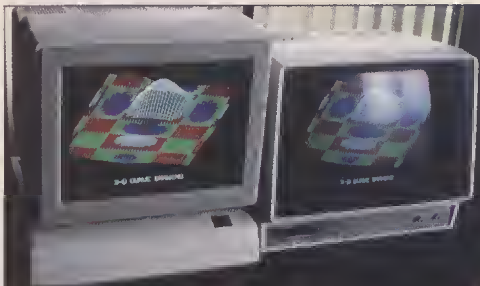
The alternative—putting a hi-fi speaker into a TV set—presents a problem of its own: adequate reproduction of low frequencies requires the speaker to move large volumes of air, ordinarily making it too large to fit in a normal-size set. But Zenith has introduced a set, incorporating a new speaker design

developed by Bose (Framingham, Mass.), in which sound waves resonate in two rectangular tubes to produce louder bass in a smaller volume than has been possible before. Bose claims that the set's 4.5-inch woofer (bass generator) puts out sound comparable to a six- or eight-inch woofer of conventional design.

The result has impressed most listeners. "It's a real knockout," says Raymond Boggs, a market researcher at Venture Development (Natick, Mass.). Leonard Feldman, a Long Island–based consultant and senior editor of *Audio* magazine, agrees, calling the sound "much better than anything heard from a TV before." The Bose speakers drive up the price of a Zenith set by \$300–\$500, to as high as \$1700.

Another Zenith development would give a similar quality boost to TV pictures. In conventional color TVs, electron beams are directed to the appropriately colored phosphor dot by holes in a metal "shadow mask" suspended in front of the curved glass faceplate. This summer, Zenith announced a picture tube in which the shadow mask is stretched taut in front of a flat faceplate. The tension improves color fidelity by preventing the distortion that can otherwise occur as the mask heats up under sustained electron bombardment. In addition, there's virtually no glare from the flat screen—both because of its geometry and because a flat piece of glass can economically be treated with an antiglare coating. Zenith claims that the flat tension-mask tube will be 80% brighter than a conventional cathode-ray tube at equivalent levels of resolution and contrast. The tube will appear first in computer terminals, but as costs fall it should eventually be suited for TV sets.

Digital signal processing, just starting to be seen in commercial sets, could literally change the face of TV. Basically, the idea is to store an incoming signal in memory, then manipulate the digitized data either to improve picture quality or to create special effects. A Toshiba set, for example, uses digital techniques to display two programs at once: an image from a separate video source (such as a videocassette recorder) appears as a small inset in a corner of the screen, superimposed on the main video display. Thus you can watch the news while monitoring a football game—at a quarter or a sixteenth of normal size—tuned in on the VCR.



Below: Bose's waveguide brings fuller sound to TV-sized speakers in a Zenith set. Left: Zenith's flat screen cuts glare.

Such features represent only the first application of digital techniques to TV; Toshiba's set came out in 1984. Newer sets will offer subtler advantages. This fall, for example, Toshiba introduced the first set in which all 525 horizontal scan lines are filled in all the time.

Ordinarily, a TV displays each image frame as two "interlaced" fields, each lasting a sixtieth of a second; one field contains odd-numbered scan lines, the other even scan lines. Interlacing avoids the flicker that would be seen if the entire picture changed every thirtieth of a second, but it somewhat coarsens the image. Toshiba's noninterlacing set fills in the lines normally left blank with memorized lines from the previous field. Thus at any moment, half the scan lines appearing on the screen come from the currently transmitted field, the other half from the previous field. The same digital memory that eliminates interlacing also lets the Toshiba set freeze an image off the air (the sound proceeds normally). The 26-inch noninterlaced sets are listed at \$1500, versus \$1000 for conventional sets of the same size.

Remote control gets less strenuous

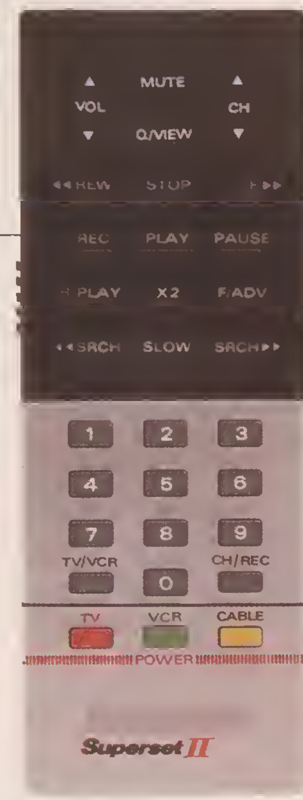
Much to the delight of the couch potatoes among us, most home entertainment systems can be operated remotely with a hand-held keypad. But all this convenience has its price; after a few equipment purchases, keypads start to clutter the living room, and it's easy to lose track of which one works the TV, the cable box, the VCR, the videodisc player, the compact disc player, and so on. According to one estimate, 2.5 million U.S. households have three or more remote controllers. While many companies assure compatibility between remote controllers for their entire product line—the controller supplied with RCA televisions, for example, also operates the company's VCRs—consumers generally don't want to be locked into a single make.

But help is at hand, in the form of new, "universal" remote controllers from North American Philips and General Electric. Philips packages its video controller with high-end Magnavox and Sylvania brand TVs, which are priced at $400 and up. To program the unit for, say, a videocassette recorder, you point it at the VCR and hold down two buttons. The controller then emits infrared signals in a variety of formats (such as short pulses, long pulses, continuous wave). When the VCR responds, you let up on the keys and the controller memorizes the code that worked. Having thus identified the VCR's "language"—a procedure taking about two minutes—the controller can actuate all its functions (e.g., play, rewind) without additional programming.

Setting up GE's Control Central is less automatic. The unit, which can be trained to control audio as well as video equipment, is placed face-to-face with the keypad it is intended to duplicate. Then you simultaneously press the same function key (such as channel up) on both keypads; the process must be repeated for each function. One advantage of the GE unit is that it comes as a stand-alone item, for less than $100. Moreover, its teach-and-repeat technique makes it capable of emulating virtually any infrared code—including those that may be introduced in future remote-controlled products. By contrast, the Philips system, with its built-in set of codes, risks obsolescence.

A third universal controller is being readied by CL-9 (Los Gatos, Cal.), whose founder and chairman is Steve Wozniak, of Apple Computer fame. CL-9 plans to make a controller that simplifies rather than merely duplicates the functions of other controllers. The unit will offer "macro" entries, wherein the push of one button accomplishes common series of tasks that now require several actions. To set up for viewing a movie on your VCR, for example, you could program the unit so that a single keystroke turned on the VCR, activated switches routing the video signal to a projection screen and the audio signal to a component hi-fi system, turned the hi-fi on, and dimmed the room lights.

A built-in clock in the CL-9 controller will simplify unattended recording from multiple sources, according to engineering VP Chuck Van Dusen. If properly programmed before going away for the weekend, for example, the unit could signal your VCR to tape PBS's *Wall Street Week* Friday night and a cable-transmitted sporting event the next day—plus turn on your audio tape deck Saturday evening to capture public radio's *Prairie Home Companion.*



Universal remotes let you direct various home entertainment units from one hand-held keypad. North American Philips packages its video-only unit (bottom) as an accessory to high-end TV sets. GE's Control Central (top), which can operate hi-fi equipment as well, is marketed as a separate product.

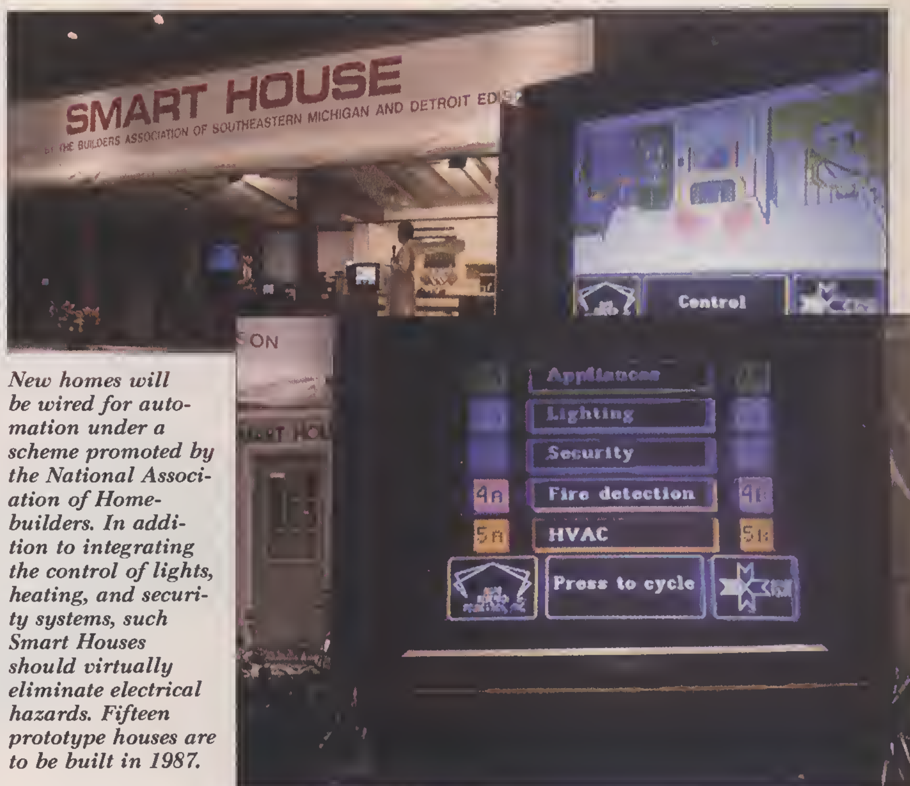
The Smart House ties it all together

Consumer control over electronic equipment will get even more sophisticated with the introduction of a proposed data link that would tie together not just entertainment systems but also such home appliances as dishwashers, lights, burglar alarms, furnaces, and air conditioners.

Under consideration for several years by the Electronic Industries Association (Washington, D.C.), the so-called Home Bus would provide a two-way data highway using several media to connect virtually everything electrical. Infrared beams could handle remote control within a room. Simple on/off signals could be sent to lights and appliances directly through the power line. Larger volumes of data could go through additional installed wiring. A network of coaxial or fiber optic cable might simultaneously deliver video and audio channels from several sources—e.g., cable box, VCR, and compact disc player—to TVs and speakers in different parts of the house.

Home Bus won't become a reality until consumer electronics companies agree on how to encode and transmit the signals. But the logjam may soon break; General Electric recently submitted as a standard its Homenet protocol. No other proposals have come forth, and by the end of the year EIA will vote on whether to accept Homenet, according to Judson Hofmann, a vice-president of Matsushita Technology (Secaucus, N.J.) and chairman of EIA's Home Bus committee. Products compatible with the Home Bus standard should appear in 1987, says EIA's Thomas Mock.

Some Home Bus features are already available. Rabbit Systems (Santa Clara, Cal.), for example, recently introduced a product that enables a single source of video programming to be connected to as many as five TVs throughout the house. A transmitter at the VCR or cable box sends signals through up to 150 feet of cable to receivers located at sets in the bedrooms, kitchen, or other rooms. Control signals such as on/off and channel up/down—emitted by a hand-held remote controller pointed at the receiver—zip through the cable in the opposite direction. Rabbit says it has sold over 300,000 of the systems since their introduction around mid-year, and figures that the potential market is much larger. Some 35 million U.S. households have one VCR and more than one TV set, estimates Gary Cummings, Rabbit's vice-president of operations and product development.



ANDREW SACKS/BLACK STAR

New homes will be wired for automation under a scheme promoted by the National Association of Homebuilders. In addition to integrating the control of lights, heating, and security systems, such Smart Houses should virtually eliminate electrical hazards. Fifteen prototype houses are to be built in 1987.

The National Association of Home Builders has organized a consortium of appliance and electrical equipment makers to adopt a "Smart House" standard that would go far beyond mere remote control, aiming to transform the way houses are wired. Under one innovation, called programmed power, wall sockets would provide an appliance with the specific kind of power it requests—low-voltage direct current for electronics, high-voltage dc for variable-speed motors in heavy appliances, high-frequency ac for ultra-efficient fluorescent lights, and ordinary juice (110 volts, 60-cycle ac) for most other loads.

In addition, current will flow to a socket only as long as the appliance plugged into it continues to transmit a signal acknowledging that the power is being received. The main purpose of this closed-loop approach is safety. A short circuit in the wall could not start a fire, because the short would not transmit a power-requesting signal to the power controller; and for the same reason, you wouldn't get electrocuted if you stuck your finger in an outlet.

The Smart House will clear a major hurdle in January with the publication of the revised National Electrical Code, which is the basis for most states' building regulations. For the first time, the code will make specific allowances for both programmed and closed-loop power. The coming year will see the construction of 15 fully functioning prototype Smart Houses, according to Hank Levine, marketing director at Smart House Development Venture (Upper Marlboro, Md.), a for-profit arm of NAHB. Then, in 1988, the venture plans to construct about 100 demonstration houses. Auspiciously, NAHB is represented on the Home Bus committee, and the two groups appear to operate harmoniously.

At this writing, contractual agreements to make Smart House equipment have been signed by six companies: Honeywell, probably the leading maker of thermostats and other energy management devices; AMP (connectors); Square D (circuit breakers and other power equipment); BRIntec (cable); Lennox Industries (furnaces); and Pass & Seymour (plugs and receptacles).

Pocket TVs are looking sharper

Video junkies can choose among a growing array of miniature TV sets. The liquid crystal displays used in most of these gadgets have improved markedly over the past few years; some pocket TVs are now actually viewable.

The biggest advance has been the adoption of "active matrix" addressing of the LCD: each picture element (pixel) is switched dark or light by its own transistor. Active addressing produces higher contrast than is possible with the older "multiplexed" method, where a pixel is activated by the addition of voltages at the intersection of row and column electrodes. So far only Panasonic has introduced an active-matrix LCD set. The other major suppliers—Seiko, Casio, and Citizen—still use multiplexing.

Panasonic first showed its three-inch-diagonal screen last January, but products did not make it to U.S. stores until this fall. Less than one inch thick, Panasonic's Pocket Watch has a resolution of 372 by 240 pixels—comparable to that of a similarly sized cathode-ray tube. To eliminate the perceptible color stripes that mar some LCD sets, Panasonic slightly offsets the color filters in one row from those in the next. The company claims that this offset also improves color accuracy because the three filters form a symmetrical triangle, with the blue and green filters equidistant from the red. Another selling point of the TV is its contrast; with the set directly in front of the viewer, white appears 50 times lighter than black. Although contrast diminishes as viewing angle increases, the head-on contrast is high enough that the picture remains viewable through a range of 40° in either horizontal direction, 30° vertically. The Pocket Watch sports a premium price tag to match its performance: suggested retail is $479.

On the lower end, Casio continues to improve its liquid crystal TVs based on the older multiplexing technology. Casio's current 2.6-inch sets, which sell for $250, have barely more than half the pixels of the Pocket Watch. Next year, however, the company will introduce a four-inch set, priced at $299, with some 60% more pixels than the Panasonic set. Casio's TVs lack the wide viewing angle that active-matrix addressing brings to Panasonic's, but company president John McDonald contends that this is only a minor drawback, because in typical use, only one person views the set at a time.

Panasonic's Pocket Watch approaches the resolution of a CRT. Thin-film transistors at each pixel bring better contrast and wider viewing angle than other LCD TVs.

Even the best liquid crystal TV lacks a cathode-ray tube's picture quality. Ordinary tubes are too bulky and power-hungry for real mobility, but a new breed of flat CRTs promises to change that. Refining a technique pioneered by Sony, Sanyo has developed a three-inch CRT with full color. Like the Sony Watchman, Sanyo's TV is flattened by turning it sideways; electrons travel the length of the set to strike a tilted phosphor screen.

Conventional color CRTs use three electron beams—one for each primary color—and a shadow mask to channel each beam. Varying the relative intensity of the beams produces a full palette of colors. Sanyo miniaturizes the set by doing away with the shadow mask and two of the electron beams. Color phosphors are laid down in vertical stripes. As the beam scans across the stripes, it turns on and off to produce the desired hue at each location on the scan line. Such "beam indexing" makes more efficient use of power than a conventional tube, where most of the electrons unproductively collide into the shadow mask. The Sanyo tube, less than two inches thick, consumes only about 5 watts and can operate off a 12-volt battery. Picture quality suffers, however; the tube displays only 145 pixels per scan line, about half the resolution of a conventional TV. The company has not announced marketing plans.

All miniature TVs, regardless of display type, tend to get poor signal reception because of their small antennas. Most sets, however, have input jacks that allow direct connection to a video source, such as a VCR or a rooftop antenna. In one helpful application, the pocket TV provides on-the-spot playback of video footage just shot with a camcorder; it's easier for a group of people to view one of these tiny screens than to watch the playback through the camcorder's electronic viewfinder.

Video games try for a comeback

First came the boom—millions of video game machines invaded U.S. homes in the late '70s and early '80s, bringing crude (and repetitious) approximations of Pac-Man, Space Invaders, and other games that so thrilled arcade goers. The craze subsided almost as quickly as it arose, though, and most observers assumed that another fad had run its course. Surprisingly, the last year has brought the introduction of three new game systems—from Atari, Nintendo, and Sega Enterprises—offering sharper pictures, subtler colors, and more varied game play than the first generation of machines.

The Nintendo Entertainment System, for example, comes with a 10-inch-tall robot that plays the game along with you. The "robotic operating buddy" (R.O.B.) stares at the TV with its photosensor eye, following instructions that are coded as flashes of light on the screen. The player's hand-held control panel can be switched between two modes so that it either directs action on screen (as in conventional games) or activates the robot, which contributes to different games in different ways.

In "Gyromite," the robot's hands grip a joystick that controls the position of obstacles on the screen. In order for the game's on-screen hero to pass safely, the player must anticipate blockages and, using the controller, direct the robot to remove them. "It teaches kids how to delegate responsibility, and it forces them occasionally to stare at something outside of the screen," says Howard Phillips, product planning manager at Nintendo of America (Redmond, Wash.).

Another Nintendo accessory, a lightweight plastic rifle called a Zapper, also offers an opportunity to step back from the TV. You point the Zapper at the screen to shoot the target—flying fowl in "Duck Hunt," bad guys in "Hogan's Alley." Pulling the trigger opens a shutter on the photosensor-equipped gun; for a thirtieth of a second, the screen blacks out except for the target, which emits a series of light pulses at a certain frequency. A "hit" occurs if the gun's photosensor registers pulsation at the target's frequency. Of course, the farther away you stand, the more challenging the game. Sega's game system includes a similar gun.

In another innovation, Nintendo offers several programmable games that the player can alter to keep things interesting. In Excitebike, for example, you can design your own motorcycle track, laying out jumps, mud holes, and other obstacles in any order, creating a course that lasts up to 10 minutes, according to Phillips.

Although introduced in the U.S. just this year, the Nintendo machine is already a huge success in Japan, where it is marketed as the Family Computer System. Over 8 million of these computers—one for every 15 households—have been sold in Japan, says Phillips.

The first wave of home video games petered out in part because the fad's quick-profit aroma enticed many companies to rush to market with games that were poorly designed and sometimes not fully debugged. To avoid a recurrence, all three game-machine companies are maintaining tighter control over who can make software for their systems. Each game machine contains a proprietary security code, which a game cartridge must match if it is to work. There's one important exception: Atari's new 7800 system is compatible with uncoded cartridges that were designed for the old Atari 2600, by far the most popular of the first video game machines.

The new game machines exploit recent strides in semiconductor technology. Because of the limitations built into the ubiquitous Atari 2600, game programs could not exceed about 8 kilobytes (KB), so they had to be made much simpler than the arcade games; the 2600's graphics circuitry, for example, could handle only two moving characters, plus three "bullets." Today's home games can afford much more expansive programs, commonly stretching out to 128 KB. The graphics processing chip in the Atari 7800 treats each pixel independently, essentially conquering the moving-object limitation. And the 7800

Operating control buttons in response to coded flashes of light on the screen, Nintendo's 10-inch-high "robotic operating buddy" makes video gaming a team sport (sort of).

Digital audio tape: Winding up for '87

A new audio medium is expected to arrive during 1987, combining the excellent fidelity of compact discs with the recordability and erasability of magnetic tape. Like CDs, digital audio tape (DAT) will use 16 bits to encode each sampled piece of the sound waveform.

The single-sided DAT cassettes, which will resemble conventional analog tapes except that they will be about twice as thick, will provide up to two hours of playing time. In the DAT player, a pair of recording/playback heads mounted on a tilted, spinning drum will move diagonally across the width of the moving tape. This setup, similiar to that used in VCRs, enables denser packing of data than the stationary heads of analog decks.

Digital decks are at hand, but audio makers don't want to distract consumers from CDs.

DATs will be able to record from such analog sources as LPs, conventional tapes, and microphones. Although they will also be able to tape from CDs, the digital bit stream from a disc player cannot be fed directly into a DAT. To allay concern by the recording industry that digital tape would let consumers make perfect duplicates of commercially distributed CDs, DAT standards writers made the two media incompatible. As a result, the deck will have to take an analog output from the CD and redigitize it, slightly degrading the sound.

While technical standards for digital tape are now firmly set, it may take some time for machines to hit the market. The developers of DAT are the same Japanese hi-fi companies that sell CD players, so they may want to ride the digital disc wave for the time being. "There's no incentive for any of these companes to get out in front with a product that's going to distract consumers from CDs," says Raymond Boggs, a market researcher at Venture Development (Natick, Mass.).

CDs retain some strong advantages over digital tape. For example, the CD's laser scanning head can hop to any point on the disc quickly, allowing CD users to program playback of the tracks in any sequence without causing long delays between selections. Also, digital tape is susceptible to wear from repeated playings, whereas CD scanning entails no physical contact. And then there's cost; DAT machines will initially sell for close to $1000, according to David Birch-Jones, national marketing manager at Onkyo (Ramsey, N.J.), which is expected to be one of the first to announce a product.

Recording on a digital tape deck will demand stricter attention than users of ordinary tape are accustomed to. It will be critical, for example, that the signal level stay within the tape's digitizing ability. "The machine has only enough bits to encode sounds up to a certain loudness," explains Michael Riggs, senior editor of *High Fidelity* magazine. "Run out of bits and you get god-awful distortion."

Greater computing power lets the new game systems produce richer graphics than the machines that started the video game craze a few years ago. Shown is "Pole Position" as it appears on Atari's recently introduced model 7800 (right) and on the old 2600 (left).

can produce 256 colors, versus 16 for the 2600. The larger programs also allow the games to better match the players' skill by providing more closely spaced difficulty levels.

Changes are coming not just in the games themselves but in the form of distribution. Sega programs its games onto slabs of plastic roughly the size of credit cards. Although their capacity of 32 KB falls short of conventional cartridges, the cards are easier to store and carry; it's easy to imagine a kid stuffing 10 of them into a coat pocket for a visit to a friend's house. One possible problem: the exposed metal contacts on the card surface invite short circuits due to static electricity.

While sales of video games have plummeted over the last several years, the trend may be reversing. "The business did not die," stresses Nintendo marketing VP Ronald Judy, who predicts that the industry's 1986 sales will surpass last year's by 35%. The company expects to have sold 1 million game machines in 1986, and thereafter to penetrate 3% of U.S. households each year. At Atari, video game chief Tom Sloper says that "1986 was the year when it was once again possible to make money in video games."

"It's reasonable to assume," says Venture Development's Boggs, "that there's still a lot of consumer interest" in video games. Boggs points out that Atari, Nintendo, and Sega all have solid businesses in the arcade market, and says that the success of their new products will depend largely on how closely the more limited home systems duplicate the arcade experience. □

Herb Brody is a senior editor of HIGH TECHNOLOGY.

For further information see **RESOURCES**, *p. 68.*

THE LIGHT STUFF: BURT RUTAN TRANSFORMS AIRCRAFT DESIGN

The man behind *Voyager* is out to conquer the air with fiberglass and foam

by T. A. Heppenheimer

During the 1930s, the advent of lightweight aluminum structures opened vast opportunities for such aeronautical pioneers as Donald Douglas, Jack Northrop, and Howard Hughes. Half a century later, the arrival of aircraft structures built with composite materials—carbon-epoxy, fiberglass, aramid fiber, and plastic foams—has also created a host of opportunities. But rather than found major new industries, modern aeronautical entrepreneurs have had to content themselves with filling specialized requirements for small or lightweight aircraft.

Robert Adickes, president of Avtek (Camarillo, Cal.), for example, assembled a team of top-flight designers to create the Avtek 400, an advanced twin-turboprop business aircraft. Carl Prise, cofounder of Old Man's Aircraft Company (Reno, Nev.), has overseen development of the more conservative Laser 300 single-engine craft. But no one typifies the new breed of aeronautical entrepreneurs and the problems that confront them better than Burt Rutan, president of Scaled Composites (Mojave, Cal.). Rutan has undertaken pathbreaking construction in foam and fiber, but has found his commercial opportunities increasingly restricted. In response, he has turned to building one-of-a-kind aircraft, often of highly specialized design, for customers in in-

Burt Rutan (left) "rearranges parts in unusual ways to solve problems."

MARK GREENBERG/VISIONS

dustry and government. He has also perfected the art of maintaining a low profile, refusing almost all interviews and requests for photo sessions.

Aerospace analyst Wolfgang Demisch of First Boston (New York) describes the 43-year-old Rutan as an "aerospace hacker" with an intuitive grasp of the physics of flying. "He really understands airplanes, and can rearrange their parts in unusual ways to solve problems," agrees John Roncz, an aerodynamicist who has worked with Rutan since 1977. "When he says, 'I have a hunch that this is what we need,' I've never seen him be wrong."

The soundness of Rutan's aeronautical intuition is demonstrated in the design of the lightweight *Voyager* experimental aircraft that set records for continuous, unrefueled flight last July. "It's a structural breakthrough," asserts Roncz of the delicate yet tough craft. "If you gave Lockheed or Boeing the problem of designing a craft that carries 8000 pounds of fuel yet weighs 950 pounds when empty and without engines, they could not do it."

Blown about by heavy winds, the tiny plane flew 11,600 miles in a looping course over the California coast, notching 111 hours of continuous flight. Piloted by Burt Rutan's brother, Dick, and Jeana Yeager, *Voyager* unofficially broke the 55-year-old endurance record for continuous flight and the 24-year-old distance record for nonstop flying over a closed circuit. What's more, the mission was just a preliminary to a continous round-the-world flight planned shortly.

Rutan's stock-in-trade is a set of techniques for low-cost construction of one-of-a-kind aircraft. As his basic materials, he normally uses styrofoam or urethane foam (at a density of four pounds per cubic foot), fiberglass, and epoxy. The foam forms a stiff core for the fuselage and wings. The builder cuts it with an electrically heated wire, almost as if he were trimming balsa wood for a model aircraft. Templates, fixed to each end of a long foam block, define airfoil shapes; by running a stretched hot wire along the templates, the builder shapes the wing to its proper form. Then he covers the wings and fuselage with layers of epoxy-impregnated fiberglass. This technique requires no wing spars or other structural members; the fiberglass shell itself takes all the loads, while the foam filling adds stiffness. The method has allowed individuals to construct flying aircraft at home for as little as a few thousand dollars.

Rutan has also introduced innovations in aircraft shapes. Many have featured canards—small wings set forward of the main pair to influence a plane's aerodynamics. In addition to a center of gravity, an airplane has an aerodynamic center, around which it pitches in flight. The two centers must be well separated, to prevent the craft from sustaining a pitching oscillation, called the phugoid, that makes it hard to control. For stability, the aerodynamic center must be placed to the rear—meaning that the plane tends to nose down. To counteract that, the aircraft needs an auxiliary set of wings. These normally take the form of tail-mounted horizontal stabilizers, which tend to pull the tail down and thus require that the main wings be large enough to offset this loss of lift. The forward-mounted canards, by contrast, are true auxiliary wings. They produce positive lift, carry part of the plane's weight, and allow the main wings to be smaller and lighter.

Canards aren't new; they date back to the Wright Brothers' Flyer. What Rutan did was build them with new, lightweight materials and treat them as second wings, using the canards in combination with the main wings to create what amounted to biplanes whose wings were mounted fore and aft. That overcame a major problem experienced by previous designs incorporating canards—a lack of stability that could cause the plane to flip over on its back when pitching upwards.

Rutan has introduced innovations in the shapes of aircraft and the materials used to build them.

Rutan's interest in original designs emerged when he was in high school, and helped him to win national trophies for model aircraft. Later, as an undergraduate at California Polytechnic State University at San Luis Obispo, he won first prize in a national student competition sponsored by the American Institute of Aeronautics and Astronautics, for a project that applied aerodynamic theory to the yawing of a model aircraft. Rutan also invented a method of using his car as a wind tunnel. He mounted an aircraft model on a long boom stretching out of the car window, to remove the model from the disturbed airflow near the car, and drove full tilt down a road, using instruments inside the station wagon to collect data on the model's performance.

After graduating with honors in 1965, Rutan joined the technical staff at Edwards Air Force Base, the Mojave Desert home of the Air Force's top test pilots. He started off writing test manuals, but his unusual ability quickly won him management of his own flight-test project: the Low Altitude Payload Ejection System, designed for delivery of supplies to ground troops in Vietnam. The system, which did not go beyond the experimental stage, used parachutes to pull a sled with a 25-ton load from the cargo hold of a transport aircraft flying just ten feet off the ground. While gaining management experience, Rutan realized that he preferred to work for himself, without red tape. "It takes three weeks to get a photo taken here!" he once complained.

In 1972, he grasped an opportunity that, in effect, enabled him to serve an entrepreneur's apprenticeship. Taking a long-term leave from the Air Force, he moved to Newton, Kans., as head of aerodynamics for Bede Aircraft. There he designed a jet-powered version of the BD-5, a high-performance piston-engined plane for the private pilot market. His creation eventually gained fame with a role in the James Bond movie *Octopussy*. But the piston-engined version of the BD-5 encountered serious problems during development, driving Bede toward bankruptcy. Rutan decided to go it alone, and returned to Mojave to set up the Rutan Aircraft Factory, intentionally using the same initials as the Royal Air Force.

RAF's initial products were construction plans for a home-built aircraft that Rutan had designed to resemble the Swedish Viggen fighter. Called the Vari Viggen (because its canard could be varied in flight), the wooden plane had already received a warm reception at air shows and hobbyists' gatherings. That enthusiasm did not translate into widespread sales of the plans, but in his next venture Rutan put together all the ingredients necessary to commercial success.

To build an experimental craft that incorporated an air-cooled Volkswagen engine, he used a fiberglass-on-foam technique that he had already applied to radio-controlled models. Nobody had used such materials for a piloted aircraft with an engine, and Rutan initially thought of the technique as a mere stopgap. But as his tests continued, he realized that the construction technique combined speed and simplicity with strength. In fact, the design was able to support an O-200 engine from Continental (Montgomery, Ala.) when the lighter Volkswagen proved unreliable. The resulting plane, named the Vari Eze, had a cruising speed of 175 miles per hour and a top speed of 200 mph—far beyond the performance of other home-built planes. Rutan sold about 6000 sets of instructions for the Vari Eze, at $100 apiece. Licensing ar-

DESIGNER PLANES

PAT STORCH

RUTAN AIRCRAFT

CHRISTOPHER SPRINGMAN

Rutan's aircraft designs feature lightweight materials and low-cost construction. The Grizzly (top left) has a short takeoff and landing capability; Rutan built it for his own use. The Vari Eze (center) and Long Eze (top right) formed the basis of his success in selling kits to home builders. He designed Voyager *(bottom) strictly to chase endurance records.*

Paul MacCready: Aviation's part-time pioneer

One of the few aeronautical entrepreneurs whose fame rivals that of Burt Rutan is better known for winning aviation awards than for selling aircraft. Over the past decade, Paul B. MacCready's use of lightweight materials to design human-powered aircraft has earned him several hundred thousand dollars in prize money and abundant media coverage, but the aircraft haven't created new markets for his company. Aerovironment (Monrovia, Cal.), the firm that MacCready founded 15 years ago to exploit research in fluid mechanics, has instead continued to generate revenue with the same kind of projects it has pursued from the start: air pollution and hazardous waste management, wind power, and the design of instruments for atmospheric measurements. "The aviation projects," says MacCready, "have been sponsored for publicity."

There's no doubt of their success in those terms. The whole world seemed to notice MacCready's first foray into aviation history a few years ago, when he won the £50,000 prize offered by British industrialist Henry Kremer for the first human-powered flight along a figure-eight course around two pylons half a mile apart. While most of the unsuccessful entries had resembled balsa-wood model planes, MacCready tried another approach. He designed his *Gossamer Condor* as a very large wire-braced hang glider. A vertical strut supported the wire bracing and a single wing spar, made of chemically milled aluminum. With bicycle racer Bryan Allen as both pilot and engine, the craft flew the course and took the prize in August 1977.

Two years later, Allen piloted the *Gossamer Albatross*—a modified version of the *Gossamer Condor* based on composite materials and carbon-epoxy to save weight—across the English Channel. The 60-pound aircraft, with a wingspan of 96 feet, won MacCready £100,000 offered by Kremer, as well as a blizzard of publicity for Du Pont (Wilmington, Del.), which paid most of the venture's $220,000 expenses.

Next, MacCready teamed up with Du Pont to design a solar-powered airplane. One of the *Solar Challenger*'s main innovations was a strengthened main wing support, which made it possible to dispense with the *Gossamer*'s vertical strut and wire bracings. Based on a structural tube of carbon-epoxy, like that of the *Albatross*, the 47-foot spar weighed just 30 pounds. A total of 16,128 solar cells generated the craft's power; on a clear day they could provide over a kilowatt, at least three times what Bryan Allen could generate. In July 1981, they powered the *Solar Challenger* 163 miles from France to England.

Then, MacCready once more went after Kremer money. This time £20,000 awaited the first human-powered craft to set a speed record by completing a 1500-meter triangular course in less than three minutes. MacCready spent $80,000 to build a new aircraft, the *Bionic Bat*, by adapting the simple and relatively strong structural design of the *Solar Challenger*. "We built the *Bionic Bat* for the fun of it," MacCready declares, "to spiral in a thermal, at the same speed as a hawk." In 1983, the craft flew the course in 2 minutes, 39 seconds, but it failed

rangements with Wicks Aircraft Supplies (Highland, Ill.) and Aircraft Spruce and Specialty Co. (Fullerton, Cal.), two of a small number of suppliers of high-quality fiberglass and plastic foams, added to his income.

The Vari Eze proved not to be the very easiest. Its plans called for a hand-cranked propeller, and the plane was so sensitive to its controls that some of Rutan's associates described it as a hot rod. So Rutan developed a new airplane, which he called the Long Eze. A slightly larger engine, the O-235 from Lycoming (Williamsport, Penn.), permitted use of an alternator and starter, and Rutan's design smoothed out the handling qualities. The net result: the Long Eze instructions, at $200 each, outsold the Vari Eze plans.

Meanwhile, another opportunity appeared, as Rutan undertook consulting work on experimental aircraft. Traditionally, aerodynamic tests have taken two forms—wind-tunnel models, and engineering prototypes of production aircraft. In 1982, Rutan and his long-term associate Herbert Iversen formed a new firm, Scaled Composites, to offer a third type of test: piloted scale models, built quickly and inexpensively on a one-of-a-kind basis using composite materials.

Test models for wind tunnel studies can cost from $200,000 to $2 million, including instrumentation. They yield measurements of lift, drag, pitching and yawing moments, side forces, dynamic loads, pressure distributions, and coefficients that define the aircraft's ability to steady itself following a disturbance. A flying prototype adds much more: handling qualities, stall characteristics, maneuvering loads, aeroelastic bending (oscillation of wings and fuselage), engine noise, fuel economy, speed as a function of power, and structural and fatigue tests. But the price tag is several times higher, and an engineering change made at the prototype stage not only tends to alter more than one aircraft system but can also force expensive changes in the production tooling.

Rutan quickly realized that his construction technique combined speed and simplicity with strength.

Rutan's demonstrator aircraft represent a reasonable alternative. Design characteristics such as aerodynamics, distribution of stiffness, power plant, method of engine installation, and total weight can all be incorporated into a demonstrator aircraft built with the fiberglass-on-foam technique, even if the final aircraft is of conventional aluminum construction. The key is finding the appropriate means of extrapolation between the two. The demonstrator craft can be loaded down with ballast to provide the correct weight, for example, and engineers can quite readily develop the appropriate equations for comparing other characteristics of a demonstrator with those of the real thing. Rutan did not pioneer the concept of demonstrator craft—the famous X series of Air Force experimental aircraft had been of this type—but he put the principle into practice by building the first acceptable demonstrators with lightweight materials.

Scaled Composites, with 43 employees, occupies a 30,000-square-foot hangar on the edge of Mojave Airport. Its design methods are, to say the least, informal. "We use a lot of TLAR—'that looks about right'—and then use personal computers mainly to check our seat-of-the-pants feeling," explains Roncz. "Aerodynamics is like an equation where the first three terms give 99% of the answer. If you understand the physics you've got that. Most people spend too much time modeling the last 1% to death. We leave that to the flight testing"—and, of course, to Burt Rutan's unique feel for flying fundamentals. "I've seen people sit and stare at flight-test data for hours, wondering why the airplane was behaving that way," says Roncz. "Burt will take one look at the data and immediately un-

to qualify for the award on a technicality and a group from MIT scooped the prize before MacCready could set up another flight. However, the *Bionic Bat* subsequently won two Kremer prizes of $6000 for 5% improvements in human-powered flight speed.

How have Aerovironment's engineers managed to adapt to different demands in human-powered flight? Part of the secret is the ability to build prototypes quickly and to change them rapidly during flight tests. MacCready is notorious for having kept tabs on the parts that survived the *Gossamer Condor*'s frequent crashes. If a part proved robust, the team weakened it to save weight.

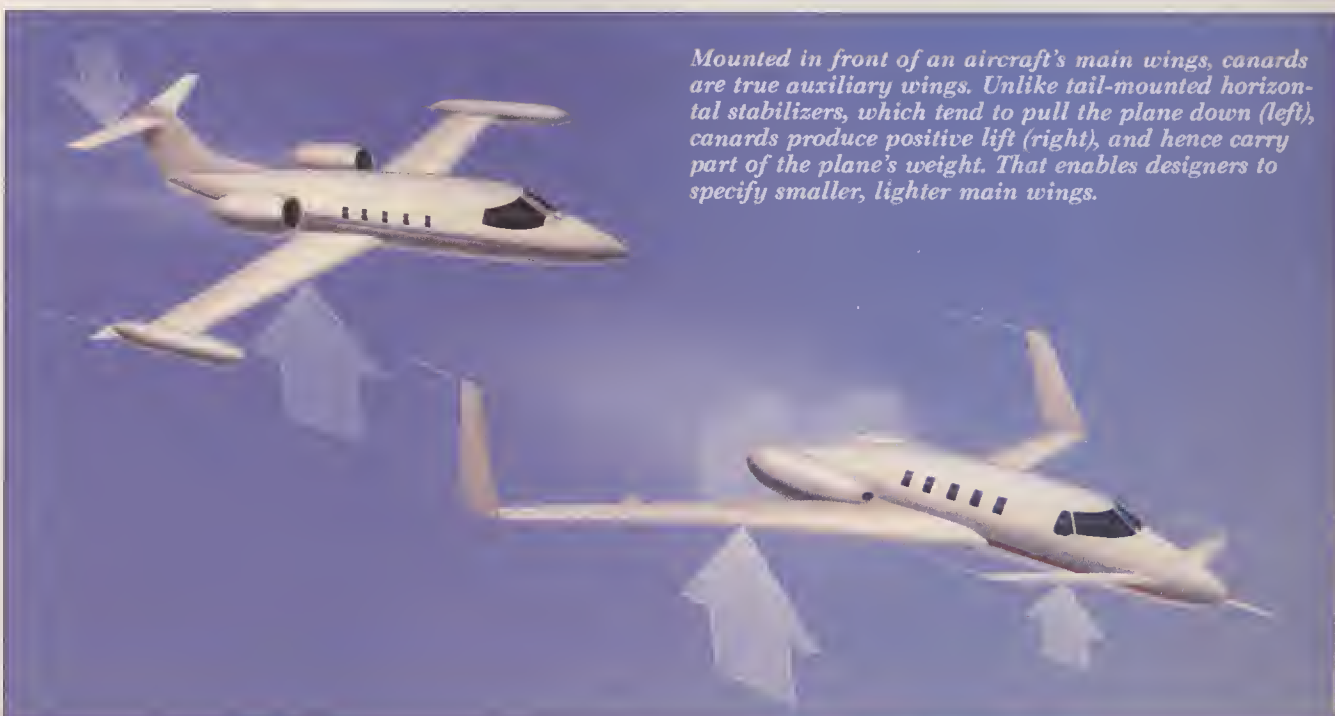
Crashes, indeed, are all but inevitable in MacCready's aeronautical exploits. His most recent venture, developed to promote the film *On the Wing*, sponsored by the Smithsonian Institution and Johnson Wax, met a spectacular end. A $500,000 half-size replica of a pterodactyl with carbon fiber bones and an autopilot in its brain came hurling down as a result of a stray radio signal at Andrews Air Force Base in Maryland.

As in Rutan's case, product liability law has dissuaded MacCready from marketing his human-powered planes. "If you sell a low-cost airplane, you can be sued for the same amount as if you'd built a $4 million Learjet," he explains. "You have to pay the same amount of product liability insurance, about $70,000. A Learjet can absorb that in the sales price, but a low-cost plane can't."

derstand what is happening."

So the emphasis at Scaled Composites is on intuition and aerodynamic insight, with alterations undertaken as needed. "We can get out there and whack the model around," says Roncz. For example, the fiberglass-on-foam technique makes it easy to modify a wing to accommodate larger ailerons. If a pilot reports that he needs more control, the team readily makes the necessary changes to the control surfaces. Experimental or developmental craft built as demonstrators in this fashion include NASA's AD-1 oblique-wing aircraft, the T-64A military trainer built by Fairchild Republic (Farmingdale, N.Y.), the Predator agricultural aircraft of Advanced Technology Aircraft (Montague, Cal.), the Navy's Power Augmented Ram Landing Craft with turbojet engines, and the Starship business turboprop of Beech aircraft (Wichita, Kans.).

The AD-1 was built in the late 1970s to test the oblique wing, which is shaped like a surfboard and mounted



Mounted in front of an aircraft's main wings, canards are true auxiliary wings. Unlike tail-mounted horizontal stabilizers, which tend to pull the plane down (left), canards produce positive lift (right), and hence carry part of the plane's weight. That enables designers to specify smaller, lighter main wings.

The perils of *Voyager*

"This is the last major milestone in atmospheric flight," declares ex-fighter pilot Dick Rutan of the nonstop, unrefueled flight around the world that he plans to undertake soon with copilot Jeana Yeager. Yet their *Voyager* aircraft, designed by Dick's brother Burt, seems too fragile to take off, let alone set milestones. True, its 111-foot wingspan rivals that of a Boeing 727. But empty of fuel, *Voyager* tips the scale at just 1858 pounds, including engines. It is basically a flying fuel tank, able to cram in 1489 gallons of fuel and two pilots who don't worry about such amenities as legroom.

Voyager's primary structural material is carbon-epoxy composite, donated by Hercules (Magna, Utah). The wing spar is a solid tube of this material. The craft has a stressed skin of sandwich construction, with Nomex honeycomb from Hexcel (Dublin, Cal.) as the core, laminated on both sides with carbon-epoxy that weighs four ounces per square foot. Laminations of aramid fabric strengthen the wing roots and other critical areas.

The engines are mounted in a fore-and-aft arrangement that Burt Rutan pioneered in his twin-engine Defiant homebuilt aircraft. The air-cooled front engine, donated by Teledyne Continental (Mobile, Ala.), generates 130 horsepower. The 110-horsepower pusher engine, also from Teledyne, is liquid-cooled. This allows much better control of the operating temperature, which must hold steady at 200° F. Highly turbulent combustion, achieved by swirling the incoming air, permits a leaner than normal fuel mixture. The engine thus achieves 20% better fuel economy than a conventional air-cooled motor. The pusher engine actually bore the brunt of the work on *Voyager*'s major test flight last July, which lasted 111 hours; the pilots shut off the front engine shortly after takeoff, to hold it in reserve.

July's flight encountered mechanical and human problems. Soon after takeoff, an electric motor controlling the propeller's speed froze in the maximum-drag position, forcing a landing (and a fresh start) after just seven hours. The canard oscillated violently, compelling the pilots to reduce speed. And a set of oil rings in the engine failed. Incessant engine noise made relaxation difficult—as did the cramped 7½ × 2–foot cabin, especially for Rutan, who is six-foot two. Rutan also lost sleep worrying about the ability of the less experienced Yeager to fly *Voyager*—and then, finally convinced that she could do it, overslept. Meanwhile, Yeager failed to eat or drink enough, losing six of her 97 pounds and becoming dehydrated.

The two intrepid aviators will face more perils on their round-the-world trip, scheduled to last 12 days. *Voyager* will be completely fueled for the first time, dragging down the wings so much that engineers will have to install outrigger wheels or recruit motorcyclists to hold up the wingtips on takeoff. During its first few minutes in the air, the fragile craft will be extremely vulnerable to downdrafts. And for the next few hours, Rutan and Yeager will have to live with the prospect that turbulence or a sudden storm could exert the 1½ g's of force sufficient to break the wings off the heavily fueled plane and deposit its occupants in the ocean.

atop a fuselage in such a way that it can be pivoted like a scissor. Changes in the wing's pivoting angle permit flight at both subsonic and supersonic speeds, in the manner of swing-wing aircraft. But the oblique wing also offers lower drag, less weight, greater range, and a much simpler structure for wing pivoting and support—qualities that have won it attention for use in naval aviation.

Oblique wings had been studied in wind tunnels during the 1970s, but NASA needed a flight test. A proposal to convert an existing F-8 naval jet carried a price tag of $5–7 million. Rutan then offered to build a fiberglass-on-foam scale model. The design was adapted to a single-pilot AD-1 aircraft powered by two small jet engines, which flew at speeds of up to 170 knots. NASA's Ames Research Center (Mountain View, Cal.) managed the project, and Ames Industrial Corp. (now named Microturbo North America) in Bohemia, N.Y., built it. Its cost, with engines: $239,000.

As work on demonstrator models took more and more of Rutan's attention away from the Rutan Aircraft Factory, the company also began to face a series of disturbances. Sales of plans to hobbyists started to decline as the market became saturated, while the increasing number of firms offering aircraft-quality materials to home builders reduced Rutan's licensing fees. Moreover, the legal climate was turning sour. Every set of plans sold by RAF carried the risk of a million-dollar liability suit. "The owner-pilot market has all but dried up, and one cause is the cost of product liability," declares William Mellon, director of corporate communications at Beech Aircraft. A significant reason, ironically, is that most aircraft are so well constructed that they can give years of useful service—and years of product liability for the manufacturer. Moreover, under the legal doctrine of "joint and several liability," a plaintiff may sue anyone remotely connected with the accident. A supplier found to bear as little as 1% of the responsibility for a mishap might have to pay the entire settlement if its resources were sufficient.

The Rutan Aircraft Factory ran afoul of product liability when some hobbyists' attorneys declared its designs unsafe. Rutan defended his firm by arguing that the plaintiffs, as builders, had not followed his plans' instructions. One set of plans, for example, directed the builder to apply seven layers of fiberglass as a wing covering, and then to mount the wing to the fuselage with bolts. A hobbyist used only a single fiberglass layer and attached the wing with epoxy but no bolts. He crashed and sued. The suit did not reach trial, and RAF paid no money to that plaintiff (or to any other). But the defense of the suit cost some $10,000. Although such legal expenses were never high enough to pose a serious threat to the firm, the litigious climate of home building made the demonstrator aircraft business look increasingly attractive.

Meanwhile, John Walsh, president of Beech Aircraft, had decided to stake his company's future on all-composite planes like the Starship. The $3.5 million Starship is an eight-passenger business aircraft with a top speed above 400 mph and a maximum altitude of 41,000 feet. Like Rutan's Vari Eze, it is a tailless design featuring canards, swept-back wings, tip-mounted winglets that serve as vertical stabilizers, and pusher propellers.

What Walsh needed was an R&D arm to develop future corporate designs. He knew Rutan and Scaled Composites well, because they had built a successful demonstrator of the Starship. But the demonstrator firm was no more than a small venture that might go under in a few years. Walsh decided to make Rutan a buy-out offer. "Most companies pay quite a lot for R&D," explains Iversen, who is vice-president of Scaled Composites. "We were doing it at a profit, and Beech said, 'Hey, we gotta get in on this.' "

Beech's acquisition, whose dollar amount has not been disclosed, carried several sweeteners. Rutan became a vice-president and board member of Beech, while Beech purchased rights to

DEMONSTRATOR AIRCRAFT

INSET FAIRCHILD

BEECH AIRCRAFT

Piloted scale models of aircraft, built quickly and cheaply on a one-of-a-kind basis, permit extensive yet low-cost testing of experimental aircraft. Burt Rutan has built demonstrators for the T-64A military trainer (top), the AD-1 oblique-wing aircraft (center), and the Starship business turboprop (bottom), among others.

his home builder designs. That relieved Rutan of the need to sell kits, and enabled him to reduce the time he spent on RAF business. He even gave RAF a new name—Composite Prototypes—to indicate its lowered profile in the home builder market. Beech also allows Scaled Composites to undertake contract work for other aircraft companies that do not compete directly with Beech.

Beech's quid pro quo is ownership of the only R&D shop of its kind in the U.S. Any other company that wants this type of in-house expertise in order to compete with Beech's business aircraft will have to build it from scratch. Already, the company is developing two Rutan-designed aircraft aimed at new market niches. The first is the Cabin Twin, a two-engine, five-passenger plane that will cost between $750,000 and $1.2 million, depending on the form of propulsion—considerably below the Starship's price tag. The second, Model 81, will be a single-engine craft, also designed for five passengers.

Those ventures suggest that Rutan will bring fresh thinking to a stale sector of the aeronautical business. "The general aviation industry's problem is that its product line is essentially 1940s vintage," says First Boston's Demisch. "Burt Rutan is one of the few people whose design skill and willingness to use new materials open up the opportunity to move forward, and Beech is one of the few companies with the resources to take that step." □

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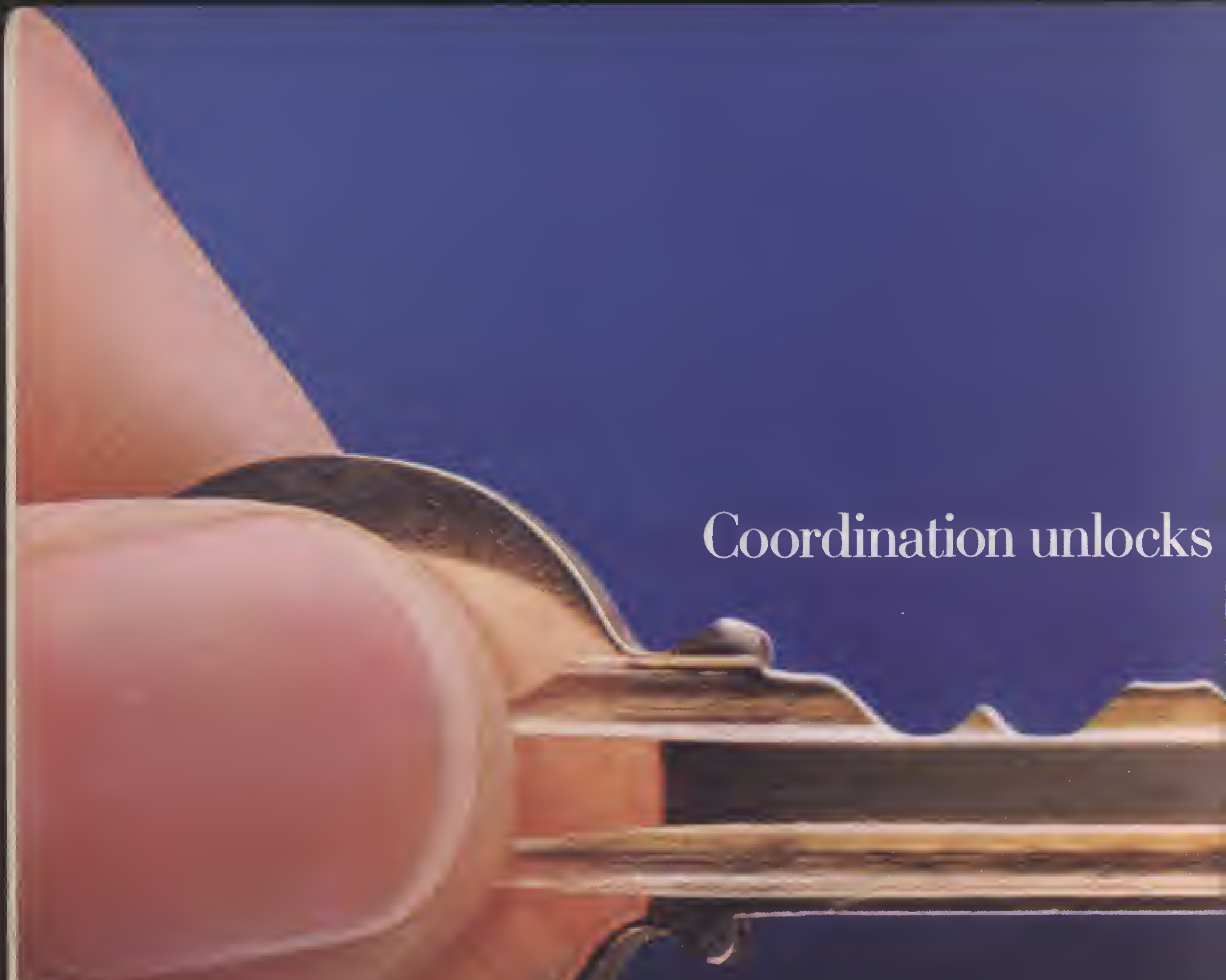
For further information see **RESOURCES**, *p. 68.*



Coordination unlocks

If you're like many manufacturers, you automate work centers one at a time, as the need arises.

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SATELLITE COMMUNICATIONS AT DOWN-TO-EARTH PRICES

Small earth stations bring private networks to a wider range of businesses

Satellite communications, once the sole province of giant corporations, government agencies, and common carriers, is now becoming accessible to a broader spectrum of business users, thanks to the arrival of very-small-aperture terminals (VSATs). Priced relatively low—$2500 to $20,000, including the dishes and their associated electronics—and using antennas that measure just two to four feet across, these earth stations can handle light to medium voice and data communications between a central headquarters and hundreds or thousands of branch offices or retail outlets.

The market for VSATs is just beginning to stir, and so far their acceptance has been mixed. In 1985, VSAT sales totaled only about $15 million, according to a study by L. F. Rothschild, Unterberg, Towbin (New York). The report, issued about a year ago, predicted that the market might reach $40–50 million this year and roughly $1 billion by 1990.

by Rick Cook

In the last year, however, Rothschild and others have revised their predictions sharply downward. One of the major reasons was Federal Express's decision this fall to cancel its ZapMail electronic mail service, which was to utilize a planned 25,000-terminal VSAT network. Largely because of ZapMail's well-publicized demise, Rothschild has cut its 1990 market projection in half, to $500 million.

Still, a half-billion-dollar market is nothing to sneeze at, and a number of major companies, including Southland, Farmers Insurance, AT&T, and RCA are continuing with their plans to install fairly extensive VSAT networks. For example, GTE is installing a network for K Mart stores that will have over 2100 of the satellite terminals with a value of $40 million when it is completed by late 1990.

Another vendor, Equatorial Communications (Mountain View, Cal.), has installed more than 20,000 receive-only earth stations for news and stock services such as Reuters and Dow Jones. "I think VSATs are going to be a big industry," says Ed Parker, Equatorial's president, "but like every new industry it will grow slowly at the front end. People always overestimate what can be done in two years and underestimate how much can be done in five."

Cutting costs. Given the right circumstances—numerous and widely separated sites, a starlike network topology in which the remote sites do most of their communicating with one or two central hubs, and information loads that are not extremely heavy—a VSAT network can reduce data communications costs by 25–50% over a conventional network of leased telephone lines, according to various industry estimates.

Meeting the networking requirements of such dispersed installations with conventional means can be a very expensive proposition in today's telecommunications environment. Costs of traditional methods of tying sites together via leased telephone lines relate directly to the distance covered. In addition, customers must pay connect charges to the local phone companies, and these fees are constantly growing. Also, the average cost per site is fairly constant regardless of the number of sites, since the bulk of the total expenditure is that of the leased lines themselves. As a result, large networks don't realize much of a per-site cost advantage over smaller networks.

Another disadvantage of the leased-line approach is that companies with a multitude of sites may have to deal with a large number of local telephone companies, each with its own rates and services. Finally, the network cost depends almost solely on the number of

ILLUSTRATION BY CATHERINE BENNETT


7-11
7-11
7-11

sites and their distances from the hub; it is largely independent of the amount of information actually transmitted.

VSAT networks have the advantage of relatively low per-site costs, which typically drop even further as the network grows, but they require a much greater up-front investment than leased telephone lines. One or more large hub earth stations, each of which can cost anywhere from $750,000 to $1.5 million, must be purchased, and leasing a satellite transponder costs about $135,000 to $150,000 per year—although customers sometimes can reduce the transponder cost by renting only part of a transponder's capacity from a reseller.

The hub station and transponder costs are largely independent of the number of remote sites, however, so extensive networks can realize per-site cost advantages; remote VSAT earth stations that can send and receive signals cost only about $10,000 to $15,000, and receive-only terminals typically sell for as little as $2500. The Rothschild study estimates the monthly cost of a VSAT system with 300 sites at $467 per site and one with 1000 sites at $307. The study notes that comparable service with leased lines would average about $1250 per month per site, regardless of the network's size.

Driven by the high costs of leased lines, Southland Corp. (Dallas) has installed VSAT terminals at about 300 district offices for its chain of 7-11 convenience markets in the U.S. and Canada. The company eventually hopes to put VSATs at all of its 7500 7-11 stores. Cost isn't the only advantage, according to Bill McMinn, manager of voice and data communications for Southland. "There is the high reliability of satellite transmissions and the ease of adding sites or making changes," he says. "If you're relocating a district office, you can move the antenna and have the terminal back up the same day. Going through AT&T takes about three months to get the phone line installed."

Satellite links are typically more reliable than their terrestrial counterparts for several reasons. These include less atmospheric interference—most "terrestrial" lines are actually microwave signals, some of which can be affected by snow and rain—and fewer data-path switches, where errors can be introduced. (The VSAT signals are also microwaves, but because they travel up to an orbiting transponder, they pass more quickly through any snow or rain and thus suffer less interference.) Typically, a voice-quality leased line used for data transmission would have an error rate of about one bit in 10,000, says Equatorial's Parker. His company guarantees an error rate of less than one bit in 10 million.

Southland's Bill McMinn says fixed-cost VSATs insulate the user from phone company rate hikes.

The cost of VSAT equipment is expected to drop as production volumes increase, as designs are improved, and as competition grows. Leased-line costs, meanwhile, are going up. State public utility commissions, under pressure to generate new revenue to subsidize residential customers, have been increasing leased-line connect charges. Philip J. Freedenberg, executive vice-president of Federal Engineering, a consulting firm in Vienna, Va., says that while "a lot of private-line rates have doubled or tripled in the last couple of years, VSATs insulate you from rate increases." Southland's McMinn agrees. "By capitalizing all the hard-


RAY GENDREAU

Equatorial cofounders Dean Mack (left) and Ed Parker see many uses for their low-speed data-only VSATs.

ware in our system over a five-year period," he says, "we have a fixed cost."

Exit Fed Ex. A major setback for the VSAT industry came in late September when Federal Express announced it was canceling plans for a 25,000-terminal, $300 million VSAT network to support the company's ZapMail facsimile transmission service.

According to Federal Express, using a VSAT network in lieu of leased lines was expected to save the company $10 million a year in communication costs, but the company couldn't go to an all-VSAT network fast enough or get an interim network that mixed VSATs and leased lines to operate efficiently. Capital costs were high, and some delays were caused by reduced satellite availability in the wake of the *Challenger* disaster. Still, Federal Express acknowledges that customer response to the relatively expensive facsimile service was lukewarm.

Even though the Federal Express decision cast a pall over an already lagging market, other major VSAT customers are continuing their VSAT projects. They include Farmers Insurance Group, which has about a third of its planned 3000-station VSAT network in place. The company uses the system for claims processing, and to receive and answer questions. Another firm, Wal-Mart Stores, has ordered 1500 VSATs for voice and data transmission.

At the same time that such companies are installing their own private VSAT networks, several third-party providers have entered the market. These companies will operate VSAT networks as common carriers, often supplying the terminals, the transponders, and the hub station for a monthly fee. Through this approach, potential VSAT customers can reduce the capital costs that are a major stumbling block when moving to the satellite technology. The third-party supplier, meanwhile, is able to spread the expense of the most costly parts of the network (the hub station and the transponder) over multiple customers.

"By not requiring a lot of investment up front, we can lower the risk threshold, and thereby lower the decision threshold," says Michael E. Gallagher, technical support manager for Comsat Technology's Network Products Division (Clarksburg, Md.). Comsat is now offering a VSAT service called Starcom with a limited capital cost and, if all components are leased, a monthly cost roughly equal to that of leased terrestrial lines. Therefore, he says, the decision to use VSATs can be made much further down in the corporation, by the people who normally make decisions about communications services rather than by the corporation's top executives. If the customer is willing to pay higher capital costs in exchange for lower lease costs, on the other hand, Starcom will sell the customer VSAT terminals at about $14,000 a unit.

Even AT&T, the nation's biggest provider of terrestrial leased lines, has gone into the VSAT utility business. Early customers for the AT&T service, called Skynet, are the American Farm Bureau (Park Ridge, Ill.) and the May department store chain (St. Louis). AT&T hopes to have another 10 Skynet customers signed by year's end.

"Leasing is a method to help customers get their feet wet with this very new technology without having to plunk down a lot of money," says Cindy

Schmidt, one of the authors of the Rothschild report. "They can try it, and if it's economically feasible they can build their own networks."

Most VSAT vendors see retail chains as one of their biggest potential markets. Gathering sales information from each point of sale via VSATs could assist retailers in improving inventory control and tracking consumer trends. "I don't think it's any secret that the retail business is becoming fiercely competitive," says David Lyon, vice-president of vendor M/A-COM's telecommunications division (San Diego). "The notion of having nationwide control over the entire mechanism is becoming very attractive."

Just how big is the retail point-of-sale market? "The replacement market alone—what's already operating on leased lines—may be on the order of 50,000 terminals," says Equatorial's Parker. And potential new markets, such as gas stations, could prove even larger.

Retail applications are not limited to the tracking of sales. For instance, while Southland will use its initial network primarily for inventory control, says McMinn, the functions will expand if the company extends its network to the store level. Possible uses could include check and credit card verification and automatic teller machine (ATM) banking services for customers.

Another important retail application is debit cards, says consultant Freedenberg. "The banks are pushing to implement them, but that will require every participating merchant to be on line to the bank's database all the time. VSATs will make that possible."

All 7500 7-11 stores are scheduled to receive their own VSAT terminals within five years.

Technology evolution. Some of the earliest private satellite networks were installed by oil companies conducting extensive exploration efforts in remote sites. Because many of these sites lacked phone lines, Freedenberg explains, the oil companies "were using very primitive methods of data transmission—they'd put the entire day's seismic data on tape and send out a helicopter once a day to pick it up."

Meanwhile, the companies were paying as much as $50,000 a day for exploration rights. As a result, custom-built VSATs proved very cost-effective, even though they were priced as high as $100,000 per earth station. With such send/receive VSATs, the oil firms could immediately relay seismic collection data back to central computers for rapid analysis.

Several factors worked to broaden the market for VSAT terminals in the early 1980s. Foremost among the technical factors was the launching of the first Ku-band satellite transponders, operating in the 12–14 gigahertz range. Previously satellite communications had been carried in the C band (4–6 gigahertz). For an antenna of a given size, the higher the frequency of transmission, the greater the data rate possible. Thus the Ku band enabled VSAT suppliers to build smaller earth stations that could carry data at least as fast as larger C-band dishes.

Another factor stimulating the VSAT market was the realization that in addition to the two-way uses pioneered by oil companies and other businesses, there were many receive-only applications for the technology. Among the early customers for one-way VSATs were stockbrokers and wire services like AP and UPI, which needed only to transmit information from a central point for dissemination to numerous remote sites. Because receive-only VSAT stations require less power and less sophisticated electronics than their send/receive counterparts, their cost was considerably less.

In the past two or three years, the market for both receive-only and send/receive VSATs has begun to segment into a high and a low end. The differentiating factor has been the ability to carry voice as well as data.

Equatorial Communications is the undisputed leader in the low-end market. The company specializes in low-capacity terminals that transmit at 1200 bits per second from the remote stations to the hub, and as fast as 19,200 bps from the hub to the remotes. While these rates are relatively low for satellite communications, they are equal to

M/A-COM

JOHN TROHA/BLACK STAR

or greater than the rates provided by most modem-based terrestrial circuits. These are the circuits Equatorial is looking to supplant.

Unlike most VSAT manufacturers, Equatorial deliberately excludes voice capability from its terminals. As a result, the terminals sell for considerably less than those of its competitors—around $2500 for a receive-only terminal and $5500 for a send and receive. Equatorial's Parker describes the company's products as the "pickup trucks" of the industry.

Also unlike its competitors, the company uses the C transmission band. Because Equatorial's products are designed for relatively slow operation, the lower-frequency C band does not preclude the use of small-aperture terminals, even though interference can be a common problem with such an arrangement. Because a two-foot dish has a beam width of 9°, and communications satellites are spaced about 2° apart, signals intended for one orbiter may also strike a neighboring satellite. Equatorial avoids this problem by using a proprietary encoding and transmission technique along with extensive error checking to filter out interference.

High-end VSATs usually operate between 56 kilobits and 1.5 megabits per second and can handle voice and sometimes video, as well as data communications. All of the VSATs in this sector use the Ku band. Unlike the low-end VSAT market, which is virtually owned by Equatorial, the high-end market is quite competitive. Among the contenders are M/A-COM (which is supplying the equipment for Wal-Mart and Southland), Avantek, California Microwave, NEC, Mitsubishi, Vitalink, Satellite Technology Managment, Telcom General, Harris Corp., Scientific Atlanta, and Comsat Technology. Customers who choose high-end equipment typically do so either because they want to send voice as well as data or, more commonly, because their applications demand high data rates.

Although high-end VSATs can support voice links, their use for this application is limited because of the inherent delay—about a quarter of a second—introduced by the time it takes the signal to travel from earth to the satellite and back. While generally not disruptive, the delay is long enough to be annoying, especially when people at two remote sites attempt to converse (in which case the delay is doubled).

Market barriers. Even with prices dropping, VSAT installation costs will remain higher than those of terrestrial links. These costs, as well as potential customers' unfamiliarity with the technology, could slow VSAT's acceptance.

In addition, VSAT vendors face regulatory issues on a number of fronts. Unlike backyard earth stations that pick up TV signals, many VSATs transmit as well as receive, so they are regulated more closely. "You have to go through the FCC to get your license, and that takes about a year," says Southland's McMinn. "The application itself is about the size of a dictionary." But because the Ku band is virtually devoted to satellite communications—unlike the C band, which is used for telephone communications, military radar, and other purposes—McMinn hopes that the FCC can be persuaded to give blanket clearances for Ku-band VSAT networks.

But even with FCC support, says McMinn, "you also have a lot of zoning and city codes to check into. And you have to get the landlords' permission to put antennas on the buildings. There's a lot more involved than simply installing the system."

VSATs let retailers control inventory and sales from their headquarters, says M/A-Com's David Lyon.

Like a lot of technologies, VSAT has not lived up to inital expectations. "It was the '300% phenomenon'—the belief that every new technology is going to grow at 300% a year," says Comsat's Gallagher. Those predictions seem to have passed, and industry analysts and companies are taking a more realistic look at the potential of VSATs. "We expect slow, steady growth over the next few years," says Rothschild's Schmidt. Equatorial's Parker agrees: "The decision times are turning out to be longer than we hoped, but the market is still out there and I'm very bullish." □

Rick Cook is a freelance technology writer based in Phoenix.

For further information see **RESOURCES**, *p. 68.*

A solo PC user becomes a one-man gang when the computer is AT&T's PC 6300 PLUS. Equipped with Simul-Task, the computer can run several programs at once.

While this user prepares a budget forecast, his AT&T PC can simultaneously print out a letter and share data with a remote mainframe, or with the work group at right.

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Users of these AT&T systems can do more, and do it faster than users of other PCs.

The difference: a bit of technological lightning called Simul-Task. Armed with Simul-Task, the solo PC user becomes a one-man gang, and the small department becomes an army—more productive as well as more efficient.

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AT&T's PC 6300 PLUS is ranked among today's premier single-user machines. The speed is intoxicating, the graphics razor-sharp. However, it is AT&T's Simul-Task that catapults this IBM*-compatible into a class of its own.

COMPUTERIZING GENE ANALYSIS

The "sequenator," capable of deciphering every human gene, will benefit medicine and biotechnology alike

Molecular biologists have long dreamed of being able to precisely analyze the human genome—the 100,000 or so genes, carried on 46 chromosomes, that are contained in every human cell. The reason is that many processes and ailments (including cancer, hereditary disorders, cellular aging, and at least some forms of heart disease) are known to be regulated by one or more genes. Knowing the chromosomal location and chemical structure of the responsible gene would provide priceless new information for medical researchers. And since gene structure is the key to producing large amounts of such commercially important proteins as interferon, insulin, and protective antibodies, industrial biotechnologists would also stand to benefit from the knowledge.

Obtaining that information may be closer at hand than anyone suspected even a year ago, thanks to a computerized device called a sequenator, developed at the California Institute of Technology (Caltech) in Pasadena and recently commercialized by licensee Applied Biosystems, a young instrumentation company based in Foster City, Cal. The sequenator is likely to be the primary tool by which the human genome is analyzed, or sequenced, because it can perform the task automatically and far more economically than existing methods. In that role, the sequenator will join DNA synthesizers, often called gene machines, and other analytical instruments as the final component of the truly modern biotech lab—a "microchemical facility" that can produce and analyze both the genetic raw material (DNA) and the various proteins that are produced under the DNA's direction.

by Ricki Lewis

"Just as the revolution in physics came with the development of atom-smashing accelerators, the revolution in biology has arrived with machines for analyzing and synthesizing human genes and proteins," says Caltech's Leroy E. Hood, a codeveloper of the sequenator. And 1975 Nobelist Renato Dulbecco, a viral geneticist at the Salk Institute in La Jolla, Cal., compares the potential impact of automated sequencing to the conquest of space.

Although Britain's Medical Research Council and several Japanese companies are reportedly developing similar devices, Applied Biosystems says it is currently the only company with an automatic DNA sequenator on the market. About half a dozen of the machines are now being tested in laboratories around the country, with full-scale production scheduled for January 1987. (Beckman Instruments in Fullerton, Cal., recently dropped its effort to develop its own automatic sequencer, citing incompatibility with the company's line of laboratory instruments.) Thus Applied Biosystems' commercial prospects are promising indeed. "I can't imagine any company that is already using Applied Biosystems' other equipment *not* buying this machine," says Stelios Papadopoulos, biotechnology analyst and VP at Drexel Burnham Lambert (New York). That equipment includes a DNA sequencer and a protein synthesizer and sequencer—devices for automatically building and analyzing proteins of medical and industrial value. The new sequenator is thus "an inevitable piece of equipment," says Papadopoulos, since it will be the final step needed to completely analyze and create both genes and the proteins they regulate.

A tedious process. Manual DNA-sequencing methods were first developed during the 1970s. However, analyzing even a small gene is still a long and tedious process, largely because of DNA's extremely complex nature.

The DNA molecule is a polymer shaped like a spiral staircase in which the rails consist of repeating phosphate and sugar groups, and each step is made up of two paired nitrogen-containing compounds called bases. There are only four types of bases: adenine and thymine (A and T), which are always paired with each other; and guanine and cytosine (G and C), which are also paired. A gene is simply a stretch of DNA several hundred bases long.

It is the sequence in which these bases appear that makes one gene direct the cell's production of insulin, another gene the construction of hemoglobin, and so on. Knowing the entire

Caltech's Leroy E. Hood with a prototype of the sequenator, which could analyze every one of the cell's 100,000 genes.

sequence of DNA in a human cell—and where a specific gene begins and ends—is thus to know which genes make which proteins (a relationship that is now known for only a few hundred genes). That information in turn is needed to understand diseases that are inherited or otherwise linked to faulty genetic instructions; at least some forms of cancer, for example, probably arise from one or more of the 40-odd "oncogenes" that have been identified so far.

The first step in DNA sequencing is to obtain a segment of the DNA molecule that contains the gene of interest. There are several standard methods for doing this, based on restriction enzymes—proteins that "snip" the DNA at specific sites. The next step is to break the gene into fragments of different sizes so that each contains a different number of bases. For a 100-base gene, for example, the longest fragment contains all 100 bases, the next-longest fragment 99 bases, and so on; the smallest fragment consists of the single base that begins the gene.

One method for fragmenting the gene, called the Sanger-Coulson procedure, is to use enzymes to remove an oxygen atom from a particular base. The alteration prevents the doctored base from reassembling into the DNA molecule, just as breaking a single wire in a telephone cable completely halts transmission. Since DNA contains four bases, the fragmentation is carried out in four separate steps, each using a different enzyme. That is, the first enzyme reaction produces only fragments ending in adenine; the second produces only fragments ending in guanine, and so on. The final base on each fragment is then labeled with an isotope.

Finally, the fragments must be sorted by size via gel electrophoresis. In this process, the mixtures containing the fragments are placed on a sheet of a rubbery compound called agarose and subjected to an electric field that drives the negatively charged fragments towards the positive pole. As the particles move slowly across the agarose, the smallest fragments move fastest, and thus arrive first at the opposite end of the agarose. The sizing is interpreted through autoradiography, a process in which the radioisotope on the fragments exposes a portion of photographic film.

The end result is an image in which all the fragments are arranged in decreasing size from one end of the agarose to the other. The base sequence is inferred by determining which base is contained in one fragment but not in the next-largest or next-smallest one. For example, if the 60th-largest fragment ends in adenine and the 61st-largest ends in thymine, then those two base positions are assumed to be A and T, respectively. The process is repeated, of course, for all 100 bases.

Safer and faster. As originally designed by Caltech, the sequenator combines the four separate experiments into one; it also replaces the radioactive labels with safer and cheaper fluorescent dyes. And thanks to the computer processing, results are virtually instantaneous, while manual methods require hours or days.

In the sequenator, DNA fragments are generated by an enzymatic reaction, then labeled with four fluorescent dyes (a different dye for each of the four bases at the fragment ends); the fragments are then simultaneously electrophoresed. As they travel down the field in order of size, each is illuminated by a low-power argon laser beam that distinguishes between the dyes. Next a detector identifies the concluding base on each fragment by distinguishing the wavelength of the attached dye, and transmits the information to a computer, which is programmed to determine the sequence.

The use of dyes rather than isotopes introduced two potential problems. One was that the dye affected the DNA movement in the electric field, but this problem was overcome by adding "linker" molecules—small pieces of DNA with known sequences—to the fragments to compensate for the weights of the dyes; a computer correction factor was also used. The other problem is that the dyes absorb light over a wide range of wavelengths, some of them overlap-

Preparing for an information avalanche

What do you do with 6 million bits of data when you know that 2 billion more are on the way?

That's the problem facing workers at GenBank, the national DNA sequence databank at Los Alamos, N.M. And even though GenBank's resources are pooled with those of its overseas counterpart (the European Molecular Biology Laboratory in Heidelberg), the expected increase in the rate of sequence submission following the introduction of Applied Biosystems' sequenator promises to be overwhelming. Asked how he plans to cope with the information avalanche, GenBank director Walter Goad says simply, "That's a good question."

GenBank is charged with maintaining all DNA sequence data in computerized form for ready access by researchers; it is viewed as an alternative to the thousands of pages of such data now published in genetic journals. "As more data are generated," says Goad, "journals are less and less inclined to print many pages of sequences. The databank is a natural place for it."

Part of the problem of logging sequence data is that DNA sequences alone do not necessarily provide meaningful information; they should ideally be "annotated" to indicate where the gene starts and stops, as well as to indicate other sequences (called "enhancers") that boost a gene's activity. Also included in the sequence should be the mysterious introns—stretches of DNA with yet unknown functions.

It all adds up to a lot of work, and the four-year-old GenBank (funded by NIH) is already two years behind schedule for some sequences. But steps are being taken to face the information onslaught to come. Personnel are being added to scan journals for new sequences, for example, and standard forms are available for researchers to submit new data. "Once the sequenator is marketed, people will be able to put data directly into a PC and send us the disk," says Goad.

But what is really needed to accommodate the information, he adds, is more cooperation from researchers. "We'd like to move from the present system, in which we go out and find the information, to a system in which most of the data come to us from authors."

ping. The result is that in some spectral regions the device can't distinguish one dye from another, leading to a very slight (about 1%) ambiguity in base assignment. However, the computer compensates by analyzing the spectrum on either side of the overlap—areas that are unique to a specific dye—and determining which of the two dyes contributes more to the overlap. Applied Biosystems is now searching for new DNA-binding dyes with nonoverlapping wavelengths.

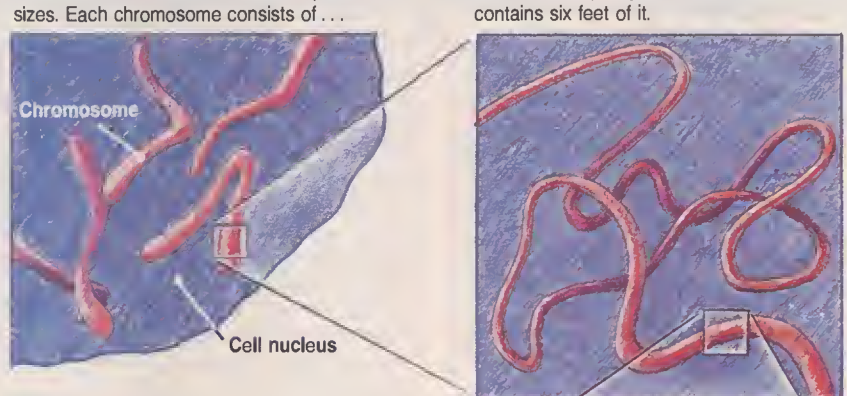
The accuracy of the sequenator is reportedly close to 99% per single strand of DNA (that is, one side of the "spiral staircase"). But the nature of the DNA molecule—in which any given base pairs up with only one other base—provides a built-in check for accuracy: the complementary strand (the other side of the staircase) can also be sequenced. The base on any one strand is confirmed simply by identifying its corresponding base on the other strand. By sequencing both strands of DNA, therefore, the error rate is lowered from 1% to 0.01%. (An error of a single base, moreover, often has little effect on determining a gene's function.)

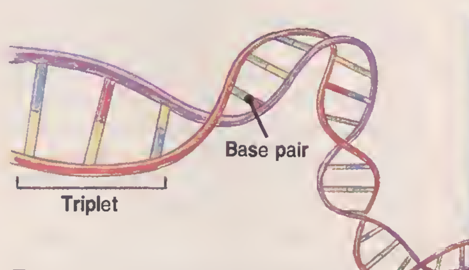
With a selling price of $90,000, however, the Caltech sequenator posed a marketing problem for Applied Biosystems. "People thought the price was pretty high," says Elaine Heron, the company's DNA marketing manager, "especially for running just one sample at a time; most researchers are used to doing eight or more samples at once. It seemed unaffordable." The company has since made the device more economical by creating a much larger gel that permits 16 samples to be run at once; future improvements will target the software and data storage capabilities, and perhaps offer automatic base recalling for checking accuracy.

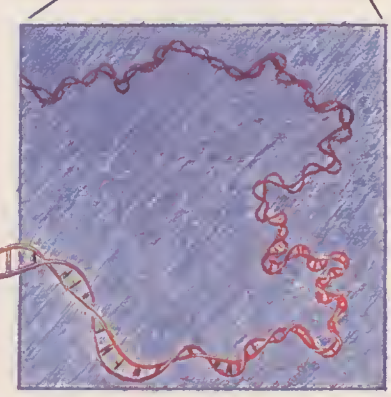
Translating genes into proteins

A. Within the nucleus of every human cell are 46 chromosomes of various shapes and sizes. Each chromosome consists of . . .

B. . . . a continuous strand of DNA, coiled so compactly that each cell contains six feet of it.







D. It is the precise sequence of the base pairs along the gene that dictates which protein is manufactured by the cell. Other cell components "read" groups of three continuous bases (called triplets), then translate the sequence into one of 20 amino acids, or protein building blocks; one triplet sequence is translated into the amino acid threonine, for example, while a different sequence leads to the amino acid called asparagine. The amino acids are then assembled into the protein regulated by the gene; a typical protein contains up to 100 amino acids.

C. The DNA resembles a spiral staircase in which each step consists of two molecules called bases; the "step" is called a base pair, and the average gene consists of about 1000 such pairs.

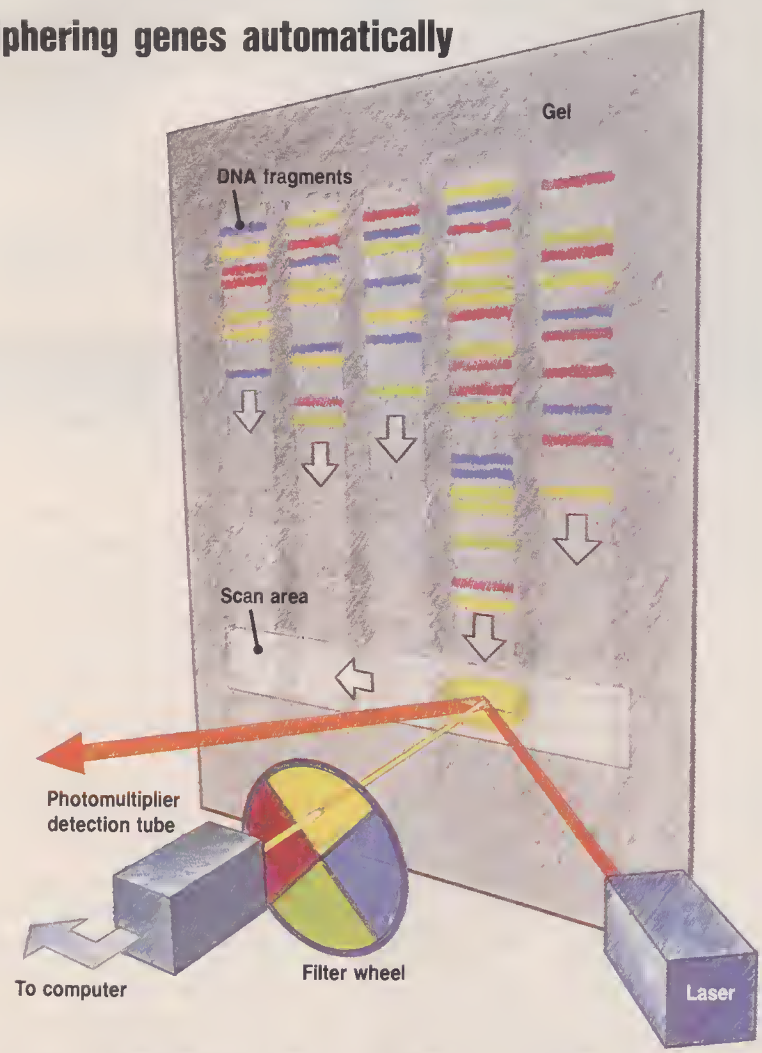
MARK ALSOP

A brief attempt at AI. Not surprisingly, other researchers have tried—and are still trying—to develop alternate versions of the sequenator. Earlier this year, for example, Beckman attempted to marry artificial intelligence (AI) technology with pattern recognition and digital image enhancement. The DNA fragments were generated and electrophoresed as in the previous case, but the autoradiograph was then subjected to a high-resolution scan—a process that combined AI and digital image enhancement and that was designed to be 20% more accurate than the human eye. "We assembled several sequencing experts and had them define a set of rules for reading any DNA sequence from autoradiographs," recalls a Beckman researcher. "We tried to address as many problems as we could, and all the rules were put into the AI system."

During the autoradiograph scan, data from the film were entered into the computer's memory; using a specially designed optical system, the image was computer-enhanced by removing background noise and carefully distinguishing between fragments of similar size. The result was said to be a highly accurate assignment of the base sequences. The product (which was to have sold for a relatively paltry $25,000) was subsequently dropped as being "basically incompatible with our line of laboratory products," according to a Beckman source. However, others cite what appears to be a fundamental redirection of the company's product line in response to a rapidly changing competitive environment. "The bioanalytical equipment business is getting very crowded," says analyst Rita Freedman of Provident National Bank in Philadelphia. "My impression is that the people at Beckman decided that they don't have a solid advantage in this type of work; they want to emphasize some of their other businesses, such as diagnostics."

In Japan, meanwhile, several research groups are also working on automatic or semiautomatic sequencing devices. For example, Seiko is reported to have developed a commercial model two years ago that automates the fragmentation step; the device was installed in only a few laboratories, however, partly because of its complexity and partly because of its stiff price tag—about $130,000. Also in Japan, researchers at Tokyo's Riken Institute are in the early stages of their own genome-sequencing project. The program is expected to utilize new automated techniques (now being developed by Fuji, Hitachi, and other corporate giants) for sequencing up to a million base pairs a day by 1988. "That sounds very impressive," says Applied Biosystems' Heron, "but they don't specify how many instruments or how many people that will entail."

Deciphering genes automatically



A gene consists of a specific sequence of nitrogen-containing compounds, called bases, that are strung along a polymer "backbone"—a repeating series of sugar and phosphate groups. Deciphering the structure of the gene, and therefore knowing the protein it regulates, means ascertaining the base sequence over the entire length of the gene.

In the Applied Biosystems sequenator, up to 16 samples of DNA fragments are poured onto a large chemical surface, or gel; each fragment is chemically bound to one of four dyes, depending on the final base in the fragment. When an electric field is imposed on the gel, the fragments migrate downward in order of size, smallest first. A laser beam excites the dye in the scan area; the emitted energy passes through a color filter that transmits only energy of the dye's wavelength, thus identifying the final base in each fragment. The sequence is deduced by knowing the length of each fragment and its final base.

Long-range impacts. For the short term, automated DNA sequencing could have a dramatic effect on laboratory productivity. Sequencing could be assigned to technicians—and perhaps even robots—thus freeing researchers for other projects. "Quite apart from the savings in time and cost, a talented researcher can now work on experimental design rather than on chemical manipulations," says Papadopoulos at Drexel Burnham Lambert. "It's the kind of thing any lab would want to do."

In another recent development, automated sequencing could help uncover the slight variations in DNA structure that exist between individuals. Several biotech companies—including Lifecodes (Elmsford, N.Y.) and Collaborative Research (Waltham, Mass.)—have begun to tap into this technology, which could revolutionize such fields as medical diagnosis, bone-marrow grafting, paternity testing, and forensics.

DNA-sequence differences are based on individual gene variations called restriction fragment length polymorphisms, or "riflips" (after the acronym RFLP); except for identical twins, no two people have identical riflips, essentially

"We're unchallenged in automatic gene analysis," says Applied Biosystems' Elaine Heron. But Japan aims to catch up.

making the variations as useful as fingerprints. Not only can riflips be used to spot genes responsible for disease—including Huntington's disease, cystic fibrosis, neurofibromatosis ("Elephant Man's disease"), and an eye cancer in children called retinoblastoma—but they can also determine whether new cells formed after bone marrow transplants arise from the donor or from the recipient, an important indicator of the procedure's success.

Riflips could also be used as legal aids. For example, comparing a child's riflips with those of the purported father would increase the accuracy of paternity tests to more than 99%. And in criminal investigations, riflip patterns could be analyzed in samples of hair, blood, saliva, and other body fluids for up to four years after a crime.

Before such applications can emerge, however, several questions must be answered—whether sequencing should be aimed first at specific diseases, for example, and even whose genome should be chosen for sequencing. The most compelling question is whether an organized effort to sequence the human genome should be made at all; enthusiasm is being tempered by some hard realities. One is the financial cost of the process: although researchers predict that the average gene can be automatically analyzed at a cost of only about $30 (versus more than $1000 with the very slow methods used today), the sheer number of analyses, in laboratories all over the country, will drive the total bill to more than $100 million. Another limitation is the time that will probably be required to complete the job—up to a decade, by most estimates. Skeptics worry not only that the time and money will be diverted from other, more pressing genetics research, but also that the usefulness of the results may be limited.

Harvard professor Walter Gilbert, who codeveloped one of the standard manual sequencing methods a decade ago, calls the program "an incomparable tool for the investigation of every aspect of human function." But others compare it to reading through an entire library just to learn about armadillos; much of the information would be useless. "We can't afford that kind of luxury," says Papadopoulos. A better approach, he says, is to concentrate on the relatively small number of genes that are known to be important to health.

Most observers are confident that the genome *will* be sequenced, if only because of the wealth of basic biological knowledge, immediately usable or not, that it is sure to provide. Moreover, many observers note the serendipity that so often attends bioresearch; in fact, the technology that gave rise to monoclonal antibodies—highly selective proteins now being used to diagnose and treat certain types of cancers—was developed in 1975 as an unforeseen byproduct of basic immunological research. "I think that we'll learn more than we expected," says Papadopoulos.

Thus whether or not sequencing the genome turns out to be the "grail of human genetics," in the words of Harvard's Gilbert, it will undoubtedly offer new insights into cell function and growth, immunology, the aging process, disease—in short, into the bewildering collection of phenomena known as the human condition. □

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For further information see **RESOURCES**, *p. 68.*

THE YEAR THAT WAS

Hardware and software are still out of balance

In broad terms, microcomputer development tends to run in spurts: first hardware overtakes software, then the software catches up and overtakes hardware. On the Apple Macintosh, the software is ahead of the hardware. In the core microcomputer market—the IBM PC and compatibles based on Intel chips—hardware is now far ahead of software.

It is two steps ahead, in fact. Nearly all MS-DOS software for the IBM PC still uses only the capabilities of the 8/16-bit 8088 and 8086 CPU chips, which can address merely 1 megabyte (MB) of memory. The immediate succesor to the 8088/8086 chips is the 16-bit 80286, which can address 16 MB. Although the IBM PC/AT and other micros based on the 80286 were introduced more than two years ago, there is virtually no software able to take full advantage of that additional power. Nevertheless, the successor to the 80286 is already upon us: Compaq, Corvus, and others have introduced micros using the 80386 chip, which can address 4 gigabytes (4096 MB) of memory. But the only thing you can do with either 80286 and 80386 micros is run the old 8088 software faster.

The MS-DOS operating system has been the main bottleneck, since it currently cannot address more than a megabyte of memory regardless of hardware; however, new MS-DOS versions should overcome the memory barrier in the next two years. One interim step will permit 80386-based micros to run several 8088 processes simultaneously, but truly powerful software for 80386 micros probably will not appear until 1988. Even though the software available now was designed for the 8088/8086, the extra speed from the newer CPUs often makes a crucial difference.

Although huge numbers of 8088/8086 micros are now in use, support for these old designs will wither quickly in the next two years. So many good software ideas can work only on newer micros that software developers will soon begin to ignore the older models. Buyers of the 8088/8086 models, after all, don't have much money to spend on software; if they did, they would buy more modern hardware.

Many companies offer speedup boards for the older PCs, and some of them even include an 80286 processor. Nearly all these boards improve only one factor—processor speed—whereas the newer micros can also perform hard disk access and other input/output tasks faster. Since the best speedup boards cost as much as trading up to an 80286 micro, you are better off selling your old 8088/8086 micro now, while it is still worth something.

If you need IBM PC compatibility, you can choose from a wide range of products that differ mainly in details and price. For 80286 micros, IBM's own offerings are limited. The latest 8-MHz PC/AT thus far comes only with IBM's 30-MB hard disk drive, inhibiting serious users seeking more storage and a faster drive. The new IBM 286/XT has a severe design flaw—the case is too small to accommodate PC/AT expansion boards, so it is out of the running. IBM's best offering is its earlier 6-MHz PC/AT with an aftermarket hard disk and a speed change to 8 MHz. Of course, IBM's micros remain expensive; you have to install accessories—additional memory, video adapter and monitor, and input/output ports—to get the PC/AT fully functional, driving the cost up further. Nevertheless, these machines are the standard, and everyone makes their hardware and software compatible with IBM specifically.

Clones generally fall into three price categories. The high-priced units from Compaq cost about as much as IBM's machines; the major clone brands, such as Leading Edge, Epson Equity, and Panasonic, fall into a middle price range; and the minor brands you probably have never heard of are the cheapest. Construction quality is only loosely correlated with price, and the quality

Toshiba produces two small computers that are the best of their type to date. The 1100 Plus (top) is an IBM PC clone with an 8086 processor and an LCD screen; it is a true portable that can run for over six hours on internal batteries. The larger and more powerful 3100 (bottom), with an 80286 processor, boasts IBM PC/AT compatibility, but its crisp plasma dipslay and built-in hard disk drive use too much power to make extended battery operation practical.

by Cary Lu

of support depends mostly on the dealer. The only important and continuing problem with all clones is keyboard "feel"; IBM makes better keyboards than any other manufacturer, at least from a mechanical standpoint.

By now, most clones are pretty compatible with IBM, particularly the PC/AT clones, which for the most part closely follow the general layout of the IBM PC/AT. Be cautious about the fast (10-MHz and up) AT clones, unless you have some technical expertise; the fast micros push components close to their limits and sometimes beyond. You should also avoid models with small chassis, which limit disk drive choices, and models with nonstandard video display adapters.

The low-cost 8088 clones vary more widely in compatibility, layout, and construction quality. If you want to buy a clone and do not have a lot of microcomputer expertise, your best strategy is to duplicate the model and configuration used by your most technically astute friend; at least you will have a way to compare notes.

Regardless of model, all micros should have at least 640 KB of RAM, a clock/calendar, at least two input/output ports (usually one parallel port for a printer and one serial port for a modem), a keyboard that can generate all standard IBM key codes, and a Hercules or EGA-compatible video board and monitor. If you need a color display, make sure the monitor has a pitch of 0.31 mm or finer; a larger pitch creates an unacceptably fuzzy image. Hard disks are now cheap enough that everyone should get one. Insist on a hard disk with automatic head parking; these heads move away from the delicate data-storage area when the power goes off, a crucial safety measure (unfortunately, these drives cost a little more).

IBM PC software has not been aging gracefully; the main core of applications urgently needs to be replaced by modern graphics-based software with a uniform user interface. The large installed base of 8088 micros has inhibited development of such software, which requires greater processing power to run adequately. Nevertheless, the first important graphics-based programs (aside from earlier CAD packages) are arriving. The Ventura Publisher page makeup program, distributed by Xerox, runs under Digital Research's GEM operating environment. Although GEM has not been widely adopted, the powerful Ventura package is much easier to learn and use than earlier page preparation programs for the PC.

Early next year, two more major graphics-based programs for the PC should arrive—PageMaker from Aldus, and Excel from Microsoft, running under Microsoft Windows. PageMaker, which will compete with Ventura Publisher, has led in its class on the Macintosh. Excel has been the spreadsheet of choice on the Mac, offering considerably more power and far smoother operation than Lotus 1-2-3 on the IBM PC. Ventura also plans a Windows version of its software in 1987.

The new desktop publishing programs for the IBM PC face major problems due to the great diversity of IBM PC software. On the Macintosh, all word-processing programs routinely deal with different typefaces and type sizes, whereas no common word processor on the IBM PC does so effectively; every program on the Mac edits text in the same way, but every program on the IBM PC edits differently. Thus you must have two different sets of reflexes to perform page makeup on the IBM PC. Page makeup will likely be better on the Macintosh than on the IBM PC for another year or more. Ultimately, many desktop publishing functions will migrate to word-processing programs; few, if any, of the current IBM PC word processors will survive the transition.

Against the steady push toward graphics interfaces, two new non-graphics products stand out, trying to take advantage of the short time before really good graphics hardware and software arrive for the IBM PC. Hercules made its reputation with its Graphics Adapter, now the standard method for putting graphics on a monochrome screen. Hercules has now brought out its Graphics Plus video board, which is compatible with the earlier Hercules format but adds software-specified fonts. Extensions of text-only display, these fonts are limited to fixed sizes and can be called up more quickly than their bit-mapped counterparts. The Graphics Plus board thus speeds up programs that include italics or boldface, such as the MS-DOS version of Microsoft Word. But ultimately, these fixed-size fonts will get little use as more flexible software and hardware routinely create variably sized fonts.

On the software side, Lotus Manuscript, a new word processor, can accommodate long, complex documents, but its interface is pure text: you must insert codes for all formatting choices, and you can see the results only after processing the file. This is no different from virtually all IBM PC word processors, but Lotus Manuscript may well be the last of its type. Future word processors will all be graphics based.

Portable computers are still selling slowly because their overall size and weight, and difficult-to-see displays, make them awkward to use. Unlike their desktop cousins, IBM PC–compatible portables come in many different shapes and with diverse features. Among true portables, which can operate for hours on an internal battery, Toshiba's 1100 Plus takes a clear lead for its attractive packaging and choice of features. But like all true portables, it is limited by the quality of its liquid crystal display. Other portables such as the IBM PC Convertible are so far bigger and heavier, and have fewer features. Toshiba's 3100 PC/AT-class micro is also appealing, although its crisp plasma display and hard disk drive are also the very features that preclude battery operation, making the machine handy but not a true portable.

The IBM PC design is now so ubiquitous that IBM no longer controls it. Even if IBM were to change its products so they could not be cloned, the software industry would not follow automatically. Clones such as the Toshiba portables improve the industry, for they supply features that IBM is unable or unwilling to deliver. And Compaq did not wait for IBM before introducing its own 80386 micro. IBM has been losing market share, not only through price competition but also through inept design and marketing decisions.

The Apple Macintosh situation is almost the opposite. Here the software is ahead of the hardware, because Apple's position as the single source of hardware has inhibited overall development. The Macintosh Plus, introduced in early 1986, has two critical improvements over earlier Macs—a SCSI hard disk port and a megabyte of memory (expandable to 4 MB). But the keyboard remains mediocre, and for some applications, Macintosh's tiny screen simply cannot display enough data. Micrografix Images, Radius, and E-machines have developed modifications that graft on a bigger screen, offering not only more area but more pixels—up to 1024 × 980, compared with the normal Mac's 512 × 342. Most Macintosh programs can already support these larger screens. Although some further evolution may take place

The Ventura Publisher page makeup program, produced by Ventura Software and distributed by Xerox, is the first important graphics-based software for the IBM PC since CAD packages. Shown from left to right is a page layout in successive stages, from screen images to final laser printer output.

inside the existing Mac box—an Apple-supplied hard disk and a single expansion slot—the next major Mac development will be a larger, 68020-based machine with open architecture. The software built into the Macintosh's ROM has inhibited clones—a pity, since Apple's hardware development has been agonizingly slow.

A hard disk is essential on the Macintosh, even more than on an IBM PC, because its graphics software takes up so much storage. The variety of hard disks available has grown quickly; most work through the SCSI port, so they run faster than the earlier external hard disks. But the many Mac hard disks are generally mediocre performers, using the old, relatively slow (typically 65–85-millisecond access time) stepper-motor hard disks without automatic head parking. High-performance hard disks for the Macintosh (with access times of 25 milliseconds or faster and auto head parking) have been hard to find, but should appear in quantity at acceptable prices in the coming months.

Macintosh software has improved steadily and continues to outperform comparable software for the IBM PC. The classic Macintosh graphics program, MacPaint, has now been improved by FullPaint. Free from the restrictions imposed by the original 128-kilobyte Macintosh, FullPaint offers multiple windows and full-screen operation. SuperPaint is the first program to combine the features of FullPaint/MacPaint (where an image is built up from independent pixels) and MacDraw (where an image consists of objects such as a line or circle), allowing you to switch between modes and use the best features of each. A third graphics package, ComicWorks from MacroMind, can certainly produce comics but is also a valuable design and layout tool for any page with a lot of graphics.

In other Mac software, MicroPhone sets the standard for comprehensive, easy-to-use communications software. Living Videotext modeled its program, called More, after a Swiss army knife: with enough assorted features, some are bound to be useful. More can produce outlines, track expense accounts, build organization charts, and generate overhead transparencies.

The Apple IIGS keeps the Apple II line going, adding more memory and 16-bit processing with new software while remaining compatible with most older Apple II software. The compatibility requirement imposed some severe technical restraints on IIGS's designers. To make the price seem low, Apple left floppy disk drives out of the main unit. Apple management also overruled engineers on the critical issue of keyboard layout, letting cosmetics outweigh practicality by placing the cursor keys in a row and leaving out function keys. (The absence of function keys may reflect an effort to keep the IIGS from looking more businesslike than the Macintosh.)

The IIGS will not expand the market for Apple II models, but it will keep many current users from switching to other machines. Containing some of the oldest microcomputer technology now sold, the IIGS will, ironically, have the greatest impact on Commodore's Amiga, whose graphics and sound-processing chips make it in some ways the most technologically advanced micro now on the market. The Amiga suffers from limited software, whereas the IIGS can draw on a huge, though wildly uneven, software base.

The IIGS will affect the Atari ST less; the ST's place in the market seems more secure than the Amiga's, as its distribution shifts away from computer stores to mass merchandisers. In terms of sheer computer power for the buck, the ST leads the entire micro market; as a total micro solution, however, neither the Amiga nor the ST has the software or hardware accessories to match a Mac or an IBM PC.

Developments in 1987 should bring software and hardware more into balance. Better software for the IBM PC and better hardware for the Mac will improve microcomputing considerably. And perhaps the microcomputer summary for 1987 will be (even) more exciting than this one. □

Cary Lu is microcomputer editor of HIGH TECHNOLOGY.

For a list of company addresses see **RESOURCES**, *p. 68.*

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COMPUTERS THAT JUST WON'T QUIT

Fault-tolerant machines are finding a niche in on-line transactions

Fault-tolerant computers—those that contain redundant hardware and special software to protect against system failures—have emerged as bright stars amidst the gloom of the computer industry's present slump. Since Tandem Computers (Cupertino, Cal.) introduced the first of these high-reliability machines a decade ago, they have found profitable, if relatively small, niches in critical real-time applications such as airplane reservation systems. Lately, the market for fault-tolerant computers has grown rapidly, as increasing numbers of businesses have instituted applications involving such on-line transaction processing.

Transactions can be defined as sequences of events that must occur as single, indivisible operations. Transferring bank funds is a typical case: when moving $100 from a savings account to a checking account, the customer and bank assume that the money will be subtracted from one account and added to the other.

Traditionally, most transaction processing has been done in batch mode, in which transactions are stored on the computer and processed in a group, usually during off hours. If a failure occurs, the computer operator can see which transaction was running at the time and restart the process where it left off. With on-line transaction processing (OLTP), however, a person interacts directly with the computer and expects immediate results. In the banking example, the customer might be using an automated teller machine located miles away from the bank's main computers. If any part of the system fails—terminals, computers, or communication lines—it will be impossible to complete the transaction.

by Charles Connell

Businesses that depend heavily on OLTP can suffer severe losses if they experience computer failures. "If our reservation system goes down for an hour during a peak period, we lose millions of dollars," says Barbara Colwell, TWA's director of reservation planning and support.

Fault-tolerant computers address this problem by operating on the premise that, while almost anything can fail at some time, it is extremely unlikely that the same two parts will fail simultaneously. By building a computer that has at least two copies of every critical component, and providing a mechanism to detect and isolate failed parts, it is possible for a computer to function almost indefinitely (see "Achieving fault tolerance").

Kimball Brown, industry analyst at Dataquest (San Jose, Cal.), predicts that OLTP customers will spend $20 billion for hardware and system software (excluding application software) during 1986 for uses such as automated banking, state lotteries, grocery store checkouts, and manufacturing control. He expects the OLTP market will grow 15% per year through 1990, outperforming general business computer growth by 300%. Brown estimates, however, that fault-tolerant computer sales currently represent only about 5% of the market for OLTP hardware and software, with the remainder going for traditional mainframes and minicomputers.

Recognizing this untapped 95% of the OLTP market, the fault-tolerant computer vendors have positioned their machines as OLTP solutions—embracing such critical requirements as communications, database management systems, and graceful growth—not just as computers that never stop.

Almost without exception, OLTP applications make extensive use of data communications. State lottery tickets are sold in corner drugstores, but the numbers must be sent to a central system. Airline tickets are sold by travel agents across the country, but the reservations are added to a common passenger list. And one bank may have hundreds of automated teller machines throughout a city. In addition, an OLTP system may have to communicate using a number of different protocols—for example, one protocol to send commands to a teller machine and another to ask the bank's mainframe if the customer has an active account.

Consequently, fault-tolerant vendors emphasize their machines' communication capabilities, such as the ability to connect to many phone lines at once and the incorporation of the latest communication hardware and software. The equipment usually can be reprogrammed to use different protocols, so it does not become obsolete as customers change the types of terminals and computers within their networks.

Database management systems are also central to almost every OLTP application. An airline reservation system is basically a database containing a list of flights and sublists of passengers on each of the flights. But although scheduling new flights and adding and changing reservations can be easily accomplished, they must be done both accurately and quickly. The manufacturers of fault-tolerant machines have responded to this need by designing database management systems specifically for transaction processing. High on the list of features is database integrity during a system crash: when the OLTP customers' systems go down, their data will not be corrupted. And when the computer is started after a crash, the database management system detects partly completed transactions and either finishes them or undoes the already completed steps and starts again.

Fault-tolerant manufacturers also offer OLTP customers something else that mainframes often lack: a growth path. "A Tandem system can begin with two processors and grow to a maximum of 16," says Terry Retford, manager of processor and memory products at the company. "If that still is not enough, a customer can expand using our networking and distributed database to connect up to 255 systems together. None of this requires changing a single line of code, and it can be done while the computers are running."

The total-solution strategy seems to be working. Tandem Computers and

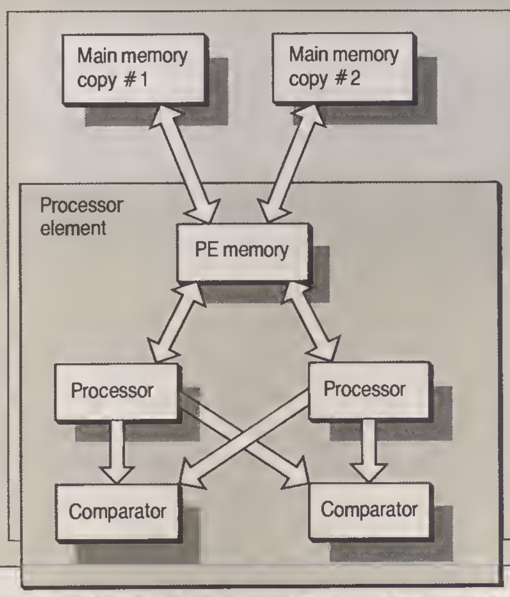
Achieving fault tolerance

Many schemes exist for achieving fault-tolerant computation, but all revolve around two ideas: redundant hardware, to provide a backup for every component whose failure could cause the system to stop; and a method for detecting when a part has failed, so the backup can be activated.

The duplication and checking of hardware must be performed throughout the computer system: power supply, memory, internal path from memory to processor (data bus), central processing unit (CPU), disk drives, and communication lines. Only parts that are not critical to the system's operation need not be duplicated.

Of all these computer subsystems, the most difficult to monitor is the CPU, which actually executes user programs. Some CPU-monitoring methods are largely software-based, with a system program checking the results of application programs for errors. The current state of the art resides in hardware-based methods, however. Special devices check the results of multiple CPUs and switch off any that show a fault.

An example of this approach is the fault-tolerant design employed by Sequoia Systems (Marlboro, Mass.). A Sequoia computer contains from two to 64 processor elements (PEs). Each PE contains two identical 32-bit microprocessor chips, two "comparators," some self-correcting local memory, and two buses to transport results to the computer's main memory, of which two copies exist.



Each PE runs a different job for one of the system's users. Within each PE, the two processors run in lock step, executing the same program. Any results of the PE's calculations are first stored in its local memory. At regular intervals, the answers in the PE's memory are written to both copies of the system's main memory, first to one copy, then to the other.

How does this design achieve fault tolerance? At each step of program execution, both comparators check the results of both processors. If either comparator finds a discrepancy, one of the processors or the comparator must be faulty. When this happens, the PE sends a signal to the rest of the system that it is out of service. The results in local memory at that time are not written to main memory, since they may be incorrect. The dual comparators ensure that a failed comparator will be found as well.

Another PE sees the fault and takes over the processing. It finds the point in the suspended program where answers were last written to main memory (up to then everything was correct). It then continues the job from that point on, or activates a third PE.

The original PE could fail while writing valid answers to main memory, but the system can recover from this. Since each copy of main memory is updated separately, the corrupted copy can be refreshed from the good copy.

Stratus Computer (Marlboro, Mass.), the two leading vendors, have lately shown dramatically improved performance. For the second quarter of 1986, Tandem posted a sevenfold increase in net profits compared with the same period a year before, rising from $2.3 million to $18.1 million. Stratus reported a profit increase from $1.9 to $3.3 million over the same period. Other fault-tolerant computer vendors include Concurrent Computer (Tinton Falls, N.J.), Parallel Computers (Santa Cruz, Cal.), Sequoia Systems (Marlboro, Mass.), and Tolerant Systems (San Jose, Cal.).

Still, despite this seemingly good strategy, fault-tolerant vendors have some significant hurdles to overcome. An industry trend that is hurting their attempts to win new customers is the increased dependability of standard computers. Today's mainframes and minicomputers are considerably more reliable than general-purpose computers of 10 years ago. In addition to the increased reliability of the basic hardware components, these manufacturers have taken steps to provide some degree of fault tolerance as well. DEC's popular VAX line allows two disks to "shadow" each other, performing the same operations simultaneously. If either disk crashes, the data are still available. And the IBM 3090 contains multiple processors that enable it to withstand a variety of hardware failures without going down.

Another problem for fault-tolerant manufacturers is that a computer operation as a whole—the hardware, software, computer room, connections to other computers, and the people who run it all—may not be as reliable as the computer itself. A fact known by everyone in the fault-tolerant industry, but not often discussed, is that hardware failures account for only a small percentage of computer system failures. The more common causes of system downtime—power interruptions, communication line errors, operator errors, and software bugs—are often beyond the control of the computer vendor.

Controlling software bugs is a particularly difficult part of designing highly reliable systems. Omri Serlin, president of research firm ITOM International (Los Altos, Cal.), notes: "An assumption in many of the fault-tolerant claims is that the machines are running bug-free software. Of course, this is never true." And because fault-tolerant computers, like other computers, contain just one piece of software to perform any given function, the software looms as a potential pitfall.

Even with these qualifications, however, fault-tolerant computers can be a boon for users who have critical applications in which the temporary loss of the system is very expensive or dangerous. As more people rely on computers for a wider range of tasks, the number of such applications is certain to grow. Manufacturers of mainframes and superminis will have to respond to the market's demand for very high reliability, or see fault-tolerant vendors enjoy an even larger market share. □

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SPREADING THE STEALTH

Smooth contours and special materials help aircraft evade radar detection

by T. A. Heppenheimer

Fighters and bombers have traditionally relied on speed, maneuverability, low-level flying, and electronic countermeasures to penetrate enemy air defenses. But a new, different, and costly set of techniques has now emerged that emphasizes low detectability, or "stealth," with respect to radar and infrared detectors. Aircraft so designed have ranked among the most secret of U.S. weapons programs, with the Air Force denying that one major effort—Lockheed's F-19 fighter—even exists. However, recent disclosures are permitting analysts to detail some of these technologies and to assess their significance in aeronautical design.

Stealth technology, which Alan Benasuli, a director of the investment firm of Drexel Burnham Lambert, estimates as "at least a $5-billion-per-year industry," is central to three major projects currently under way:

- The officially unacknowledged F-19 fighter, in production at Lockheed's Burbank, Cal., facility, will generate revenues of $850 million this year, according to David J. Smith, a former Air Force pilot now with the Wall Street firm of Sanford C. Bernstein. There's plenty more to come, he says, as the Air Force plans to buy 300–400 extra planes over the next decade. Joseph F. Campbell, an analyst at PaineWebber, estimates that the Pentagon has spent $2.6 billion in the past four years on the stealth fighter, whose mission is to go into heavily defended areas without escort and destroy enemy radars.
- Northrop Aircraft (Hawthorne, Cal.) has built a mammoth facility in Palmdale, Cal., called Plant 42, to produce the stealth bomber, known as the Advanced Technology Bomber (ATB). According to the Department of Defense, 132 ATBs will cost $36.6 billion. The bomber is scheduled to make its first flight in December 1987, with the first squadrons joining the Air Force in 1991 or 1992.
- General Dynamics (San Diego) is undertaking a $6 billion program to build the Advanced Cruise Missile (ACM). It will supplant Boeing's air-launched AGCM-86B cruise missile, whose procurement has been cut back from 4348 units to 1499. The ACM's key feature appears to be increased range, which will allow its carrier aircraft to stand off at longer distances for greater protection.

Stealth techniques cannot totally protect planes from detection. The objective of U.S. stealth technology is simply to reduce the radar visibility of aircraft in combat situations. Stealth planes and missiles are designed to elude the short-wavelength radars carried aboard fighters and anti-aircraft missiles. The fact that they are visible to the longer-wavelength search radars is less important, because those radars must eventually hand over the images of the stealth craft to fighters.

Stealthiness, which stems partly from avoiding the slablike surfaces and right-angle joints that make such craft as the B-52 bomber very radar-reflective, can appear inadvertently. The structure of the Learfan 2100 business aircraft, built by Learjet (Reno, Nev.), consists largely of carbon fiber, which absorbs radar as effectively as a carbon-rich chicken absorbs microwave energy in an oven. The Learfan's fuselage features streamlined and rounded shapes, its engines are completely buried within the fuselage, its propeller is made of radar-absorbing Kevlar, and its tail has no right-angle corners. As a result, the Learfan has proven so difficult to spot on air-traffic control radars that the Federal Aviation Administration has ordered it to be equipped with two transponders, so that it can be seen if one fails.

Military aircraft have also gained stealth through synergism in design. The fuselage of Lockheed's 20-year-old SR-71 reconnaissance aircraft, for example, features long, thin extensions to either side, known as chines. Designed to generate added lift from the fuselage, they also break up any radar beam that comes in from the side, greatly reducing the echo. In the case of the B-1B bomber, the wings and fuselage meld smoothly together, reducing not only drag but also radar reflectivity.

Designers seeking stealth also complement such shapes and materials with radar-absorbing coatings. Alcoa's Global Analytics Division (Rancho Santa Fe, Cal.), for example, has furnished a radar-absorbing covering for Northrop's stealth bomber. John Pike, an aerospace analyst at the Federation of American Scientists (Washington, D.C.), describes such coatings as more like linoleum than paint. Iron filings suspended in a base of rubbery epoxy dissipate incoming radar waves. Such coatings are most effective against short-wavelength radars: the longer the wavelength, the thicker the required coating.

Aircraft designers are also using principles applied by Emerson and Cuming (Canton, Mass.) in anechoic chambers. These rooms, used to test radar equipment, are lined with sharply pointed pyramids of ferrite material. Radar signals striking the pyramids break up and bounce between their sides, and are absorbed as the signals penetrate to the troughs at the pyramids' bases. The test-chamber walls return no echo, even though the radar transmitters are only a few feet away. A variation of this approach, which features wedges rather than pyramids, is used on the leading edges of the SR-71's wings and also on the B-1B. The spaces between the wedges are filled with insulating material such as fiberglass. As in the anechoic chamber, radar waves bounce between the wedges and are absorbed. Similarly, the skin of the F-19 fighter consists of many small, flat panels of radar-absorbing material, according to Bill Sweetman, technical editor for the Interavia Publishing Group. The materials produce a slight radar echo. But the panels, or "faceted surfaces," break up the faint reflection into tiny beamlets, further weakening the radar return.

Engines pose a tougher problem. In

conventional designs such as the pod-mounted jets of the B-52, they are excellent radar reflectors. Their inlets are virtual conduits for radar waves, while their compressors and turbine blades produce strong images. Indeed, such fighter radars as the Hughes APG-70 and APG-71, used on the F-15 and F-14D respectively, include digital processors that can actually identify the engine, and thus the aircraft type, by counting the compressor blades at a range of some 100 miles.

The stealth cure is to hide the engines. S-shaped ducts, like those that feed air to the rear-mounted engines of Lockheed's L-1011 and Boeing's 727 commercial jets, can be lined with radar-absorbing material (RAM) to prevent radar signals from reaching the engines. Similar arrangements are used in the engine inlets of the B-1B. Recessing the exhausts within RAM-lined ducts helps as well. Another trick dates back to the YF-93 fighter design of pre-Korean War vintage: fitting the inlets flush with the fuselage.


DENNIS DAVIDSON

A flying-wing design conceals the stealth bomber's engines, crew, and nuclear weapons.

Infrared emissions from aircraft must also be cloaked. This is partially accomplished by efforts to improve fuel efficiency—the cooler exhausts in today's fanjet engines emit much less infrared radiation. Mixing in a calculated flow of outside air can cool the exhaust still further. The goal is to make the infrared emissions identical in strength to those from the earth. This is possible because exhaust gases radiate less efficiently than solid ground; they emit no more infrared radiation at hundreds of degrees than the much cooler earth.

Translating stealth principles into practice required advances in other areas of aeronautics. Designers agreed, for example, that the Advanced Technology Bomber should take the shape of a flying wing; all three competitors for the ATB contract in 1981 submitted flying-wing designs. But flying wings traditionally handle poorly, and the need to place four engines, eight nuclear weapons, and a crew compartment within the wing indicated a thick wing that could greatly limit performance by causing considerable drag. The supercritical wing developed by NASA's Langley Research Center (Hampton, Va.) overcame the difficulty. The shape of its airfoil minimizes drag, while an on-board computer that automatically adjusts the flaperons—control surfaces that serve as both flaps and ailerons—maintains the bomber in stable flight.

Cruise missiles are naturally difficult to detect; their radar reflectivity and emission of infrared radiation are both low, and they fly very close to the ground. The stealthy ACM is basically a conventional cruise missile coated with RAM whose air inlets and jet engines are concealed from view. Another characteristic provides extra stealthiness indirectly. Fuel that provides more energy per pound than conventional missile fuel increases the range of ACMs, allowing them to be fired from greater distances. That reduces the chance that the enemy will detect aircraft carrying the missiles, and hence improves their odds of arriving on target undetected.

Details of the stealth fighter are more closely guarded, even though a plastic model kit described as the F-19 has sold briskly. Most likely, says Interavia's Sweetman, the aircraft's two General Electric engines and four air-to-ground missiles are buried in the fuselage, while fuel is stored in tanks in the fuselage and the wings. Radar-absorbing materials coat the leading and trailing edges of the wings, while the tail fins atop the fuselage consist entirely of composite materials.

Stealthiness carries a high price tag. Sweetman estimates the F-19's unit cost at $40–50 million—high for an aircraft that appears to weigh less than 40,000 pounds fully loaded. The main reason: the stealth fighter's faceted surfaces of carbon-epoxy must be meticulously joined and bonded. They also are very expensive to maintain. Technicians can't just knock out dents. Because a repaired dent would concentrate the radar reflection, making the plane show up more clearly, damaged pieces must be replaced. Bullet holes would cause similar problems.

The high costs do promise benefits in protecting the rest of the Air Force fleet. The stealthy ACM, for example, may enable the B-52 bomber to continue in service; the missile will allow the B-52 to achieve the largest possible standoff distance and reduce its inherent vulnerability. The F-19s will protect conventional bombers more actively; the stealth fighters' mission will be to knock out enemy radars, thereby destroying the effectiveness of opponents' air defenses and giving B-1Bs and other less stealthy planes more time in which to locate and bomb their targets. The Advanced Technology Bombers, meanwhile, will take on two of the most serious new military threats developed by the Soviets: the SS24 and SS25 missiles that can be moved freely and rapidly by rail and road. Such mobile rockets could form the heart of a Soviet second-strike capacity. However, stealthiness could give the Advanced Technology Bombers the time necessary to find and destroy the missiles. □

T. A. Heppenheimer, a freelance writer based in Fountain Valley, Cal., has a PhD in aerospace engineering.

TREATING HAZARDOUS WASTES

Innovative disposal methods could replace landfills

A variety of new hazardous-waste processing techniques, such as plasma dissociation and infrared evaporation, are vying for government approval, public acceptance, and industry support.

The potential payoff for any new treatment method is substantial: revenues of the commercial waste-processing industry—companies that transport, treat, and dispose of wastes for producers—currently stand at about $1 billion a year, and will swell to $8 billion annually by 1990 and $13 billion by 1995, estimates Arthur D. Little, the Cambridge, Mass., consulting firm. And that's only a fraction of the total market for treatment and disposal equipment. Studies by the EPA and the Chemical Manufacturers Association (Washington, D.C.) show that about 10 times as much treatment occurs in-house by companies wishing to limit the risk of accidents during transport and outside treatment.

In addition to treating new waste, processing technology is needed for cleaning up former dump sites under the Comprehensive Environmental Response, Compensation, and Liability Act (better known as "Superfund"). By some estimates, as many as 15,000 sites need such treatment.

Despite the high demand, disposal practices remain relatively primitive, relying largely on EPA-certified landfills. This publicly renounced alternative has been favored by industry because its cost of $25–$100 per ton of waste is well below the $500–$1000-per-ton cost for incineration, the second most common alternative. But as a result of public and political pressure, few new landfills have been opened, and many have been closed as EPA continues to uncover violations or unsuitable geologic conditions. Thus the cost of landfilling is rising substantially. Also, EPA recently began enforcing the "hammer rules," set up by Congress in the 1984 reauthorized Resource Conservation and Recovery Act (RCRA). The new rules prohibit the burying of certain untreated pollutants, including dioxin, solvents, and halogenated organic compounds.

by Nicholas Basta

The approach taken by some semiconductor makers is to recycle and reuse pollutants that were formerly discarded. For example, Fairchild Semiconductor (Puyallup, Wash.) uses the Piranha-Piranha system made by Athens (Oceanside, Cal.). This method recycles about 95% of a chip maker's piranha—the industry name for silicon-etching bath—by heating the exhausted fluid to a vapor. Particulates and other contaminants are left behind for disposal, while the vaporized piranha is condensed over glass beads in a distillation column.

To help develop more new solutions to toxic waste disposal, seed money is coming from the Superfund Innovative Technology Evaluation (SITE) demonstration program, funded out of the $8.5 billion committed to cleanup over the next five years.

The Pyroplasma process developed by Westinghouse (Pittsburgh) is a winner in the first round of SITE awards. Like conventional waste incinerators, it processes organic wastes (which constitute about two-thirds of the approximately 280 million metric tons of hazardous wastes generated in the U.S. annually). But rather than burning the waste, the method reduces hazardous molecules to their constituent atoms by exposing them to extremely high temperatures generated in a plasma torch. (An electric arc between the two electrodes of the torch ionizes a gas, resulting in temperatures of more than 10,000°F as ions and detached electrons reunite.) The separated atoms then move to a reaction chamber, where they recombine to form hydrochloric acid—which is eliminated by a scrubber—and harmless compounds of carbon, oxygen, and nitrogen.

In keeping with an emerging treatment philosophy advocating portable disposal units that may travel to a Superfund site or to plants with only small waste volumes, Pyroplasma components are small enough to fit into a standard truck trailer. Portable treatment is a major new market, since the new RCRA extends EPA transport and disposal rules to companies generating less than 2200 pounds of hazardous waste a month.

Another SITE winner, Shirco Infrared Systems (Dallas), offers a truck-mounted incineration unit that separates out and burns only the hazardous part of a waste stream. To clean up accidents like sludge spills, for example, conventional incinerators must burn even the affected soil. However, Shirco begins by loading the contaminated material onto a conveyor that passes under infrared heating tubes. This vaporizes the hazardous organic compounds, freeing them from the soil so they can be collected by fans and ducted into an incineration chamber.

"Because only volatile organic material is actually burned, material flows are much less, and substantially less combustion air is needed," explains James Welsh, president of Shirco. Thus, smaller equipment may be used, and less fuel is needed. "We have already been part of waste cleanups where a processing cost of only $250 per ton was verified," Welsh says.

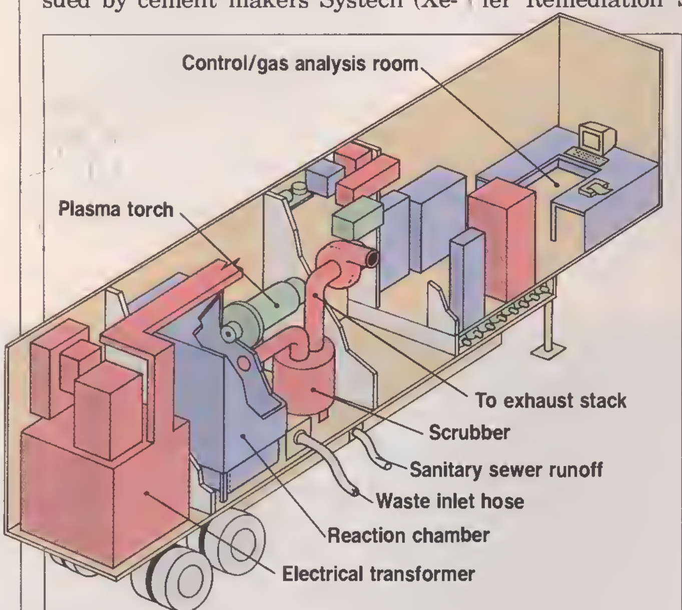
Another company pursuing the portability concept is J. M. Huber (Borger, Tex.). Its 4000°F electric-arc combustor is similar to Westinghouse's Pyroplasma technique, except that it dissociates wastes through electricity rather than heat. Six electrodes surround a cylindrical chamber, into which the waste is deposited. When energized by a high-voltage source, the electrodes create an arc through the waste in the chamber. In the presence of this electric field, the complex molecules of the hazardous compounds break down into simpler compounds. Some combustion takes place due to the high temperatures generated, but destruction of the organic waste results primarily from the chemical reactions stimulated by the electric field.

In addition to such new methods, several companies, including Combustion Engineering (Bloomfield, N.J.) and Ensco (Little Rock, Ark.), offer transportable versions of rotary

kilns—cylindrical furnaces, previously large, that rotate in order to expose all the waste to combustion.

Wide-scale portability is presently being inhibited by the absence of EPA guidelines for temporary incineration permits—the still-new concept isn't covered by current EPA rules. Portable units therefore undergo the same environmental review—at each new site—as permanently installed units. That process can take years, while most portable treatment jobs could be finished in weeks or months. However, J. Winston Porter, EPA assistant administrator for solid wastes, says the agency is likely to grant a request by the Hazardous Waste Treatment Council (Washington, D.C.) to streamline the regulatory review process for portable units. But a final ruling isn't expected for another year.

Another innovative approach to organic waste treatment is being pursued by cement makers Systech (Xenia, Ohio) and Organic Chemicals (Grandville, Mich.), who are burning organic wastes in their cement kilns in four states. Resembling rotary incinerators, cement kilns reduce limestone to clinker (raw material for cement) during an hours-long combustion process. This leaves adequate time for the complete combustion of any organic waste also dumped into the kiln. Residue from the waste, which may include nasty noncombustibles like the heavy metal chromium, are permanently locked into the concrete.



Consuming wastes with a plasma torch rather than an incinerator, Westinghouse's Pyroplasma unit is small enough to fit into a truck trailer.

In addition to new incineration techniques, the augmentation of naturally occurring microbes that eat waste continues to be pursued as a treatment method both for wastewater and contaminated groundwater around dump sites. However, researchers have so far failed to bioengineer "superbug" microbes that destroy specific pollutants completely and reliably. "You can make a designer microbe in the laboratory, but it's not likely to live in the soil or in treatment facilities," says Robert Raymond, an environmental specialist with Biosystems (Chester, Pa.). In soil "there is a complex synergy between as many as 40 genres of microbes, with one breaking down a compound that the next one degrades further. Genetically engineererd microbes have a hard time fitting into that mechanism," he explains.

Biosystems and companies such as Sybron (Birmingham, N.J.), FMC Aquifer Remediation Systems (Princeton, N.J.), Groundwater Technology (Chadds Ford, Pa.), and Bioscience Management (Bethlehem, Pa.) are having success cultivating pollutant-eating microbes already existing at a dump site. This involves "feeding" them nutrients—perhaps injecting phosphate into the soil to encourage organisms that thrive on phosphorus. To supply oxygen, Biosystems injects hydrogen peroxide into the soil, where a naturally occurring chemical reaction dissociates it into molecules of water and oxygen.

However, some pollutants—particularly halogenated hydrocarbons—aren't adequately broken down by existing microbes. Therefore efforts to engineer special life forms continue. In one approach, at Michigan State University (East Lansing), biochemist John Bumpus is attempting to identify a particular enzyme in the fungus *Phanerochaete chrysosporium* that degrades dioxins, DDT, and other compounds. If he succeeds, he plans to engineer a new generation of the fungus that's rich in that enzyme, or perhaps develop a way to make the enzyme synthetically.

Public opposition has all but written the obituary for shipboard incineration. To burn toxic wastes 100 miles or so offshore, the firms Chemical Waste Management (Oak Brook, Ill.)—the market leader in waste disposal—and Tacoma Shipbuilding (Tacoma, Wash.) built three ships with incinerators on deck and large tanks to hold wastes. At the time, expensive scrubbers were thought to be unnecessary at sea, since population centers were so far away and the ocean would presumably neutralize acidic emissions. But after 11 years of tests and public hearings, EPA has yet to issue a large-scale, long-term permit. The problem, in addition to local political opposition at the ships' home ports, is that tests at sea have proven difficult to verify.

Local opposition is generally blamed for impeding other toxic-waste disposal methods as well. Although anywhere from 10 to 60% could be disposed of by incineration, reports the American Institute of Chemical Engineers, less than 1% of the toxic waste currently generated in the U.S. goes that route. And compounding public mistrust or hostility is the painfully slow process of getting permits. For example, Waste Technologies Industries has sought permits since 1981 to build an incinerator and treatment facility in East Liverpool, Ohio, but without success. Nevertheless, there is a growing feeling that industry is becoming more sophisticated in dealing with the public, that communities are learning to weigh the risks of hazardous-waste treatment against its economic benefits, and that the regulatory process is becoming streamlined.

"I think that all the parties involved—regulators, developers, and community leaders—have become a lot more knowledgeable and a lot more realistic in their expectations," says John McGlennon, a former EPA regional administrator and now president of ERM/McGlennon Associates (Boston), an environmental consulting firm. "Things have gotten better—some communities are going to allow hazardous-waste treatment facilities to be built in the near future—but don't expect a sudden flood of new projects." □

Nicholas Basta is a New York–based journalist specializing in the chemical industry.

The next step:

Summary:

Remarkably strong ceramics have been developed over the past few years. They have not been widely used in high-stress environments, however, because of their brittle nature and relatively low toughness. But that is changing as research by GTE reveals new ways to achieve high levels of toughness in a growing range of ceramics.

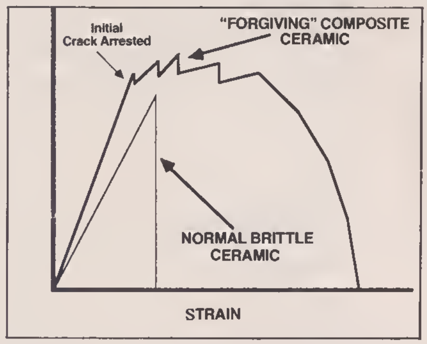
Ceramic science has made enormous strides in recent years. But the same old problem has continued to plague researchers:

Ceramics fail catastrophically, in a brittle manner.

At GTE, we are learning how to produce ceramics approaching metal-like toughness, and with strength levels even higher than presently available.

The science of graceful failure.

In traditional brittle ceramics, increasing stress causes increased strain until a critical value is reached, at which point, a crack begins and propagates catastrophically, and the component and/or part fails.



Traditional ceramics fail catastrophically at critical stress levels. Toughened ceramics (thicker line) retain significant load-bearing capability after initial cracking.

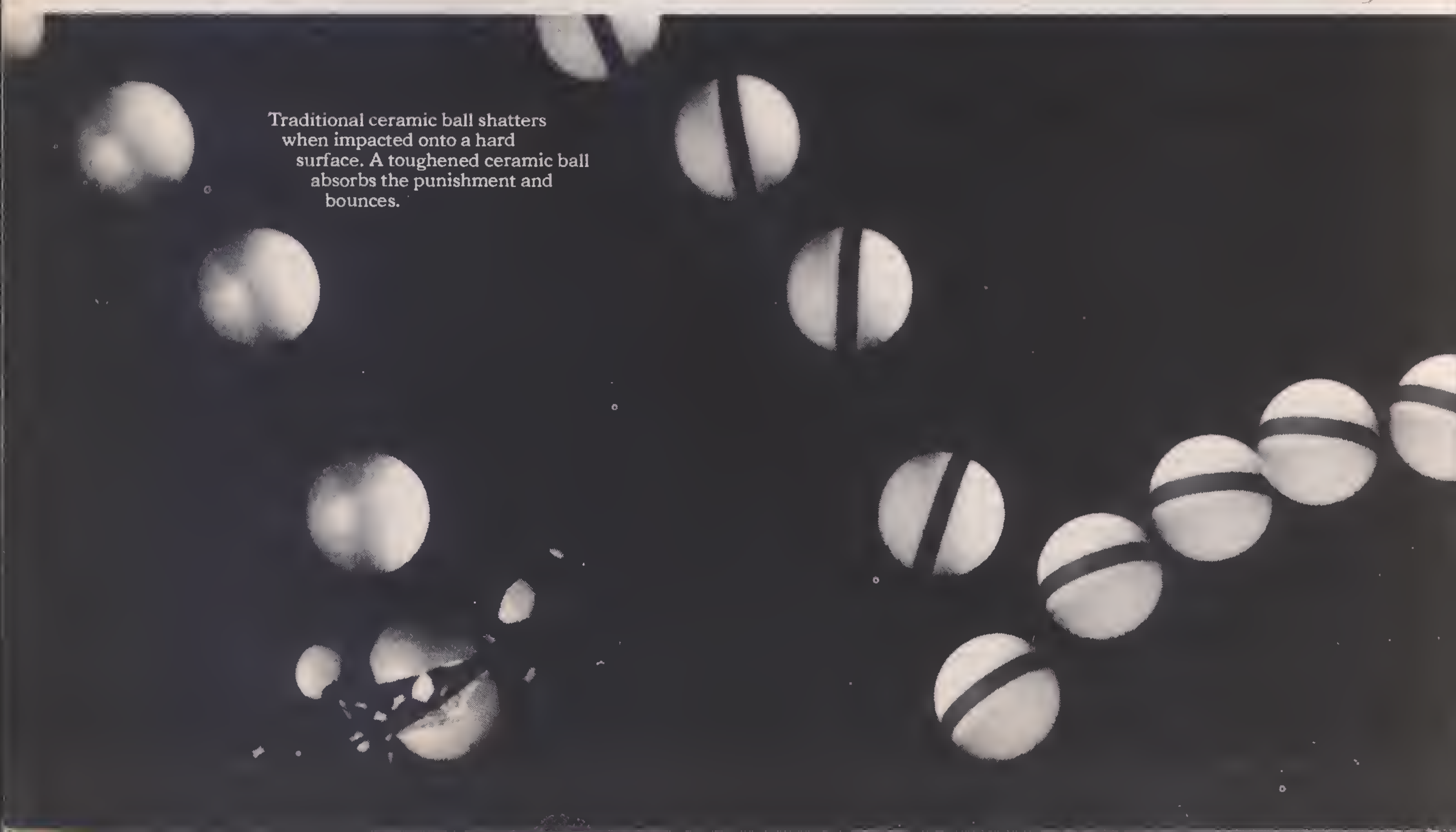
Toughened ceramics, on the other hand, fail more gracefully. A crack, once initiated, travels only a short distance before it is deflected or arrested by the toughening agent, using up a portion of the energy that produced the crack. This process is repeated many times, in effect allowing the ceramic to retain significant load-bearing capability after a crack is initiated.

In theory, there are several ways to toughen ceramics. At present, GTE is studying two of the most promising:

Tougher by a whisker.

Dispersing discrete solids throughout the ceramic matrix increases fracture toughness by promoting crack deflection. We are currently studying the effect of dispersoid size and shape (equiaxed particles vs. whiskers), as well as composition.

For example, SiC and TiC whiskers are being studied as dispersoids in silicon nitride, alumina and other ceramic matrices with great success. Toughness has been improved by as much as 40%.



Traditional ceramic ball shatters when impacted onto a hard surface. A toughened ceramic ball absorbs the punishment and bounces.

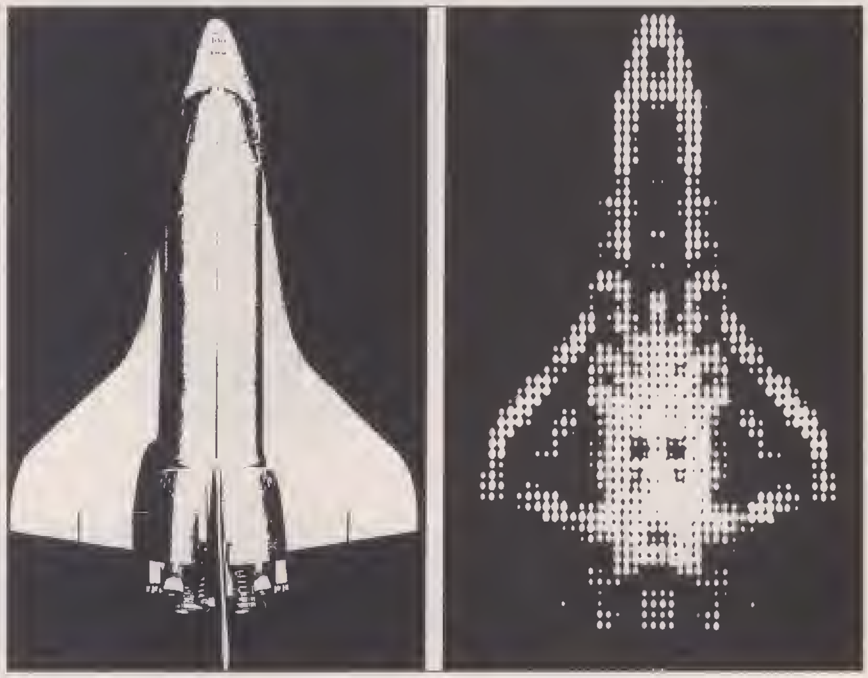
PERSPECTIVES

Super-sharp vision for radar

An imaging radar system capable of producing detailed renderings of remote targets at distances of more than 100 kilometers, and adaptable to such diverse applications as medical diagnosis and factory automation, has been simulated in a laboratory at the University of Pennsylvania. The new radar system uses a technique of interrogating the target by rapidly stepping across a range of microwave frequencies—a method called frequency diversity. Each of the frequencies produces a slightly different echo, which can be transformed to provide a composite image of the target. The resulting radar images are compared in an optical associative memory—where the elements are searched in parallel by their content rather than their address—with a library of shapes, such as aircraft types, to identify the target. According to chief researcher Nabil H. Farhat, the new radar can produce images showing details as small as 50 centimeters. In addition, the stored shapes, or characterizers, can be generated in the laboratory using detailed models for a significant cost saving.

The exceptionally high resolution of Penn's radar is a result of combining frequency diversity with angular diversity, a technique of using several small distributed antennas or sensors instead of a very large antenna.

In essence, frequency diversity produces a series of cross-sectional slices that show the target's distinctive features, just as an x-ray tomograph produces cross-sectional images of a patient's body. These slices are actually edge-enhanced—producing an outline, or primal sketch—because microwaves tend to scatter forward from flat surfaces they encounter at a glancing angle, instead of scattering back to the receiver. But visual representation of the image does not provide the best data for comparison with target characterizers, says Farhat, because of the limited capacity of the optical memory. Instead, the imaging radar transforms the range profile data into sinograms—sinusoidal traces that produce a more distinctive signature of the target. The sinograms are sampled and transformed into a digital matrix for input into the optical content-addressable memory (CAM).



High-resolution radar image of the Space Shuttle (right) was obtained from a scale model at U. of Pennsylvania's experimental microwave imaging facility.

Real-time operation is not yet possible, Farhat says, but the CAM will eventually be capable of conducting searches for target aircraft in less than a second. To identify 50-meter aircraft at aerospace distances will require approximately 50 frequency-stepping radar stations operating over 200 steps. Theoretically, the number of steps is higher—about 500—but three factors reduce it considerably. First, since the target is moving, each station has an opportunity to take more than one look over a period of time. Second, the target is symmetrical. Third, and most important, the CAM can successfully identify the target with much less than the full data set needed to "draw" a complete image—laboratory simulations indicate as little as 10%.

The research has aroused the interest of NASA, aerospace companies, and even the Port Authority of New York, which has inquired about adapting the system for traffic observation and control. Airports could use the radar through night or fog to determine if a plane's landing gear had been deployed, and its range—100 kilometers with present technology—would be sufficient to detect damaged heat-resistant panels on the Space Shuttle as it reentered the atmosphere.

Imaging radar is not limited to large objects at aerospace distances. Operating in the 40–60-gigahertz band, it could discern millimeter-level anomalies on reflective bodies, a capability that broadens its applications to robotics, noninvasive medical evaluation, and machine vision. The CAM will work with data from a broad range of sensors, including ultrasound, optical scanning, and speech recognition, says Farhat. □ —***Jack Shandle***

AM radio: Leaving the Tin Age.

Since radio broadcasting began, listeners have had to suffer the poor quality and frequent interference that characterize AM (amplitude-modulated) signals. With the growth of FM (frequen-

cy-modulated) broadcasting and the widespread use of high-fidelity home stereo systems, listeners have been hearing what they've been missing with AM. Consequently, AM stations capture barely over 25% of the listenership, even though they account for 50% of the country's 10,000 radio stations. However, moves to change the imbalance between AM and FM are being made on both regulatory and technological fronts.

The Federal Communications Commission (FCC) is helping AM broadcasters by relaxing its rules. For example, groups that own both AM and FM stations may duplicate programming so that a daytime AM station can switch to FM at night, when AM interference is highest. The FCC is also permitting increases in power levels for some stations previously restricted to low power. But the move that will have the most impact is clearing the 1605–1705-kHz frequency range for AM service, which will provide room for up to 500 new stations with recently designed, more efficient transmitters and antennas, and the capability of broadcasting AM stereo.

The National Association of Broadcasters (NAB) in Washington, D.C., has set up an AM improvement committee to raise the awareness of AM stereo among both the industry and potential listeners. So far, only 500 of the country's AM stations broadcast in stereo, notes NAB official Michael C. Rau. Only a small proportion of home or car radios can decode the signals, and few listeners are aware that AM stereo even exists.

Part of the problem derives from two competing AM stereo systems, one championed by Motorola (Schaumburg, Ill.) and the other by Kahn Communications (Westbury, N.Y.). Disagreements between the two have deflected them from the more serious business of winning acceptance from broadcasters and radio manufacturers. The few current suppliers of AM stereo radios have opted mostly for the Motorola system. Decoders that work with either system are being made by Sanyo and others, but have met with little enthusiasm.

But before listeners can benefit from AM stereo, broadcasters must clean up their monophonic signals. Most AM radio stations boost higher-pitched sounds to produce an acceptable tone on cheap radios with poor high-frequency response. This causes interference between stations. Recently, broadcasters and manufacturers agreed to reduce high-frequency boosting to give radio makers an incentive to introduce better receivers, thus paving the way for widespread AM stereo.

The NAB also seeks to limit the spectrum space occupied by each station to give them more "elbowroom" and reduce interference from overlapping signals. AM signals can currently take up a 15-kHz frequency band, but "one can achieve a perfectly decent stereo effect with a 10-kHz bandwidth," says Robert Orban, chief engineer of Orban Associates (San Francisco), a maker of transmission equipment.

Even the transmitting antenna is being examined as part of the NAB's AM checkup. Antenna design has changed little in 50 years. Now the NAB is sponsoring tests of two innovative designs for suppressing the part of the radio signal sent skyward, which interacts with the ionosphere to cause nighttime interference. The NAB hopes that by giving attention to all stages of the signal transmission chain, AM radio will be able to compete with FM on more equal terms. For listeners, any improvement will be refreshing to hear. □ *—Hugh Aldersey-Williams*

Solving AI problems with optical logic

Recent developments in the United States and Europe have brought optical technology a little closer to practicality for high-speed computing. Scientists at the University of Arizona and at Heriot-Watt University in Edinburgh, Scotland, have created optical integrated circuits that show how serial and parallel processing might be combined in a "three-dimensional" computer capable of handling massive artificial intelligence applications.

At the University of Arizona, a group directed by Hyatt Gibbs, a former Bell Laboratories researcher, has demonstrated an optical form of multistream parallel processing. Gibbs's group constructed a 2×3 array of zinc sulfide cells that parallel-processed six inputs focused from an argon laser. The device acted as a six-input logic gate for all the inputs in one step, a feat that would have taken a serial system seven steps to complete.

Dovetailing with the work in Arizona, a research team headed by Desmond Smith of Heriot-Watt University has demonstrated how groups of optical devices can be connected serially. Smith's team has constructed a three-element loop of zinc selenide interference filters in which the output of one device triggers the action of the next, in the same manner as conventional serial logic circuits. A significant step in creating this circuit was getting the optical cells to amplify. To date, optical circuits typically have attenuated the light passing through them, blocking attempts at serial integration.

Both developments are based on polycrystalline interference filter circuits. Interference filters are commonly used to limit light to a very narrow range of wavelengths—for example, enabling laser-specific photodetectors to operate without interference in daylight. The Arizona devices, which are grown on a ceramic substrate through an evaporation process similar to the process of fabricating silicon circuits, use the positive and negative reinforcement of two input laser beams to produce an output that is bistable, as in a logic gate.

The next step, according to Gibbs and Smith, is to combine the two forms of optical integration—serial connection and massive parallelism—into a rudimentary three-dimensional optical circuit. Combined, these two forms of integration could bring about a computer architecture for the future in which large arrays of data pass through a series of high-speed parallel processing elements, called "decision-making planes." The earliest applications of such an optical computer

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might be pattern recognition, image processing, and communications signal processing, Gibbs speculates.

Another possibility is a new kind of artificial intelligence system. Today's AI systems follow a serial chain of logic to reach a conclusion. For many problems, however, one chain of reasoning isn't fast enough. In recognizing a face, for example, an intelligent human looks at all the features at once, concentrates on those that look familiar, and follows parallel paths of reasoning to arrive at recognition. "You have to make educated guesses while the guesses are still worth making," says Gibbs. Only an artificial intelligence system with access to true parallel processing could duplicate such a feat in reasonable time.

Even with the current level of integration, it's too early to make predictions about three-dimensional optical computers. Real optical computing systems are at least five years away—more likely a decade, according to the researchers. Faster, higher-contrast, easier-to-make materials must still be developed before large-scale optical integration can leave the laboratory. The optics and computer industries are just beginning to wrangle over standards for optical logic architecture and materials. Nonetheless, researchers in the U.S. and Europe agree that the first steps toward optical computers have been taken with the development of small arrays. Now the major task is to develop larger integrated optical circuits with hundreds of gates. Only when such optical ICs can be fabricated reliably outside the laboratory could parallel processing optical computers become a reality. □ ***—Brad Fisher***

Double duty: Antidepressant aids in weight control

Up to 20% of Americans will suffer serious depression at least once in their lifetime, according to the American Psychiatric Association. Unlike the temporary and relatively mild letdown that often arises from personal disappointments and setbacks, such depression may require treatment with drugs. As a result—and despite such side effects as blurred vision, irregular heartbeat, and weight gain—antidepressant medication is big business in the U.S., with sales reaching some $400 million in 1985.

That market could be shaken up by a new antidepressant called fluoxetine, which has been developed by Eli Lilly (Indianapolis) and recently submitted to the FDA for approval. Not only does the drug cause fewer negative side effects than other such drugs, but it also seems to be useful for weight control. Fluoxetine may therefore become an important addition to the antidepressant arsenal and to the $66 million prescription diet aid market as well.

Severe depression has been linked to deficient levels of the brain chemicals serotonin and norepinephrine. Unlike other antidepressants (which act on many types of body tissue simultaneously and so produce the undesirable side effects), fluoxetine is highly selective. It acts only in the brain and maintains normal levels of serotonin by preventing its absorption in the synapses (the gaps between nerve endings in the brain across which impulses are passed).

Fluoxetine's value for weight control emerged during routine safety tests, when it was learned that human as well as animal subjects lost weight without dieting while using the drug. In one study, patients taking fluoxetine lost more weight than did those using amphetamines, a group of drugs often prescribed for weight loss. Although amphetamines are generally effective weight-control aids, they are not without disadvantages: they are moderately addictive, may cause hyperactivity, and gradually lose their effectiveness by inducing tolerance in the patient. Tests are now under way to determine if fluoxetine also becomes ineffective with time.

It is still not clear how fluoxetine causes weight loss. Although weight problems are common in depressed people, there is no known physiological link between the two phenomena. Researchers suspect, however, that while fluoxetine is not an appetite suppressant in the usual sense of the word, it does alter the desire for certain foods.

For example, the drug seems to reduce "carbohydrate craving," according to studies by MIT researchers Judith and Richard Wurtman, who report that people with low serotonin levels will fill up on high-calorie foods. Since starches are known to increase brain levels of serotonin, fluoxetine may act as a neurological substitute for these fattening foods. Lilly's studies also reveal that fluoxetine reduces alcohol consumption, which could also contribute to weight loss.

But fluoxetine may have some competition in the wings, primarily in the form of Wellbutrin, an antidepressant introduced in 1984 by Burroughs-Wellcome (Research Triangle Park, N.C.). Although Wellbutrin is chemically different from fluoxetine and other antidepressants, it also causes weight loss; together with its mood-altering properties, the effect had led to its use as a treatment for bulimia, an eating disorder marked by abnormally large appetite. Earlier this year, however, Burroughs-Wellcome withdrew Wellbutrin from the market after several patients suffered seizures. Even though bulimics as a group have a higher rate of seizures than the general public, Burroughs-Wellcome is studying the phenomenon before proceeding any further.

Wellbutrin's problems have not dampened Lilly's enthusiasm for fluoxetine, however. Robert Benezra, an analyst with the investment firm Alex, Brown, & Sons (Boston), estimates that Prozac—Lilly's trade name for fluoxetine—will capture 10 to 15% of the antidepressant market soon after approval by the FDA (expected by June 1987). Benezra believes that Prozac will be well received because of its performance in clinical tests: the drug seems to be very safe, weight loss appears substantial (about a pound a week), and unlike other antidepressant drugs, Prozac has a rapid onset of activity. □ ***—Salvatore Salamone***

Can scientists rescue science education?


LILLIAN KEMP

Students catch up on science basics in Harvard's Mid-Career Math and Science program—one of several efforts to turn scientists and engineers into high school teachers.

Several U.S. universities are offering education-degree programs for retired and semiretired scientists and engineers, in an effort to help stem the shortage of qualified science and math teachers in the nation's secondary schools.

This recycled-scientist-as-teacher concept started in 1966 at the University of Vermont (Burlington). Initially, the degree program was designed to encourage graduates of all kinds, regardless of their discipline, to enter teaching. "But when we began getting appeals from local industries and individuals in technical fields," says Arthur Cheney, director of the university's College of Education and Social Services, "we decided to pitch our program specifically to people with science backgrounds."

The curriculum for the programs—at Vermont, Purdue, the University of Arizona, Harvard, Bridgewater State College (Mass.), Texas Tech University, and George Mason University—have similar components. Students in Harvard's Mid-Career Math and Science curriculum, for example, take courses in education basics and adolescent psychology, as well as electives that enable them to update or expand their science backgrounds. There is also a course on the status of math and science in secondary schools to give these career changers an idea of the current challenges and problems. They then spend 12 weeks doing full-time student teaching.

The Harvard program has been successful in that all but two of its 50 graduates are now teaching. Graduate Anthony Copas, a high school math and science teacher in Utah, says that teaching satisfies his need to work with people and help develop their skills. His business experience enables him to give his students a realistic view of the working world of scientists and engineers, he says, and his experience training other employees helps with his teaching. Although he makes less than half of his former salary as a chemical engineer, Copas's enthusiasm remains undampened. "I have a burning desire to teach," he says.

Given the benefits of such programs to the business community, it is no coincidence that some of them have corporate and/or foundation backing. GTE (Stamford, Conn.), for example, has provided a total of $100,000 in grants to Harvard, and the Polaroid Foundation (Cambridge, Mass.) has also given support. Sybil Stevenson, contributions manager–education support at GTE, says the company wants to help avert "the crisis in science and math education."

That crisis is real. An estimate by The National Executive Service Corp. (New York), a nonprofit management consulting firm, puts the present U.S. shortage of high school science teachers at 11,000. But an added incentive for businesses is that such programs provide new alternatives to workers who may soon retire. □

—Helen Wheeler

RESOURCES

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Guided vehicles, p. 16

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TECHSTARTS

Analog Design Tools:

DESIGN AUTOMATION FOR ANALOG CHIPS

Analog circuits are so quirky compared with their digital counterparts, which are simply on or off, that many engineers view analog chip design as a form of black magic. While systems to automate digital chip design have been on the market for years, similar aids for their analog counterparts started appearing only recently. The software developed by Analog Design Tools automates the drawing of circuit schematics and simulates conventional tests. It can be used with engineering workstations from Sun Microsystems, Apollo Computer, and Hewlett-Packard, as well as with the IBM PC. Chief competitors are computer-aided engineering companies Daisy and Valid, which include some analog circuit design software with their far more comprehensive line of digital design tools.

Financing: $6.8 million in venture capital funding from investors including Institutional Venture Partners, Asset Management, affiliates of the Hillman Co., MBW Venture Partners, Sierra Ventures, and Alpha Partners.

Management: Curtis C. Hare (president) was CEO of Terak, a computer graphics firm acquired by Calcomp. Martin Walker (cofounder and vice-president of advanced development) was director of microwave systems for Comsat General Integrated Systems. James McGregor (cofounder and VP of engineering) was a design consultant specializing in radio frequency circuits and equipment.

Location: 800 Menlo Ave., Menlo Park, CA 94025, (415) 328–0780.

Founded: June 1983.

Curtis C. Hare, president of Analog Design Tools, hopes to take the black magic out of analog chip development.

LIANE ENKELIS

EnMasse Computer:

UNTANGLING ON-LINE BUSINESS

In computer applications such as banking and order processing, the information in large databases is in constant flux during business hours. EnMasse designed its E/CS system specifically for such uses (known as on-line transaction processing applications) by building in special logging procedures for data and by using a multiprocessor architecture that helps prevent overloads during peak demand. EnMasse is targeting banks, libraries, and law firms. It competes with makers of fault-tolerant computers such as Tandem and Stratus, whose systems have many similar features, and with mainframe computer makers such as IBM, which have dominated business computing.

Financing: $18 million in venture capital financing from investors including Crown Associates, GE Venture Capital, Hambro America, Oak Investment, Olivetti International Technology Venture, Oxford Partners, and J.F. Shea Co.

Management: Robert Gardner (president and CEO) was a partner of venture capital firm Bedminister Capital Group and previously was vice-president of sales and marketing at Auragen Systems, a now defunct maker of fault-tolerant computers. Michael Simon (VP of marketing) was VP of systems engineering at Infinit, a maker of network management equipment. William Peisel (VP of engineering) was director of engineering at Computer Design and Applications, a maker of array processors and medical imagers.

Location: 125 Nagog Park, Acton, MA 01720, (617) 263–8711.

Founded: October 1983.

Houston Biotechnology:

DRUGS TO FIGHT EYE DISEASE

One of the main goals of current biotechnology research is to produce drugs for combatting a wide assortment of human diseases. Houston Biotechnology is focusing its efforts on the eye, including retinal and optic nerve degeneration, cataracts, ocular tumors, and corneal disorders. Using recombinant DNA techniques, it is currently working on products to diagnose and treat neurological eye disorders as well as on nonaddictive analgesics. Although many other biotechnology firms are developing genetically engineered drugs, none are working in the same eye and neurological area.

Financing: $2.8 million in venture capital financing from investors including The Woodlands Venture Capital, Allstate Insurance, Inco Venture Capital Management, and U.S. Venture Partners.

Management: Founders Dominic Man-Kit Lam (chairman and scientific director) and Jared M. Emery (executive vice-president) are affiliated with the Baylor College of Medicine, where Lam is a neuroscientist and director of the Center for Biotechnology and Emery is an ophthalmic surgeon. Alfred G. Scheid (president) was cofounder, president, and CEO of California Biotechnology.

Location: 2170 Buckthorne Pl., Suite 350, The Woodlands, TX 77380, (713) 363–0999.

Founded: September 1984.

SIGNAL PROCESSING ICs: CIVILIAN SALES RISING

Audio/video and industrial uses are spawning healthy markets outside the military

Digital signal processing (DSP) provides one bright spot on the horizon for the beleaguered semiconductor industry. Digital processors are specialized circuits that convert real-time continuous signals, such as those from sound or light, into digital form. Once converted, such signals can be mathematically manipulated to improve their quality. DSP has traditionally been used for analyzing radar and sonar signals in military systems, but technological advances are now creating big new commercial markets. Worldwide sales of DSP chips and related components were $500 million last year, and Gnostic Concepts (San Mateo, Cal.) estimates that this market should reach $2.5 billion by 1990.

The promise of DSP is illustrated by the broad range of current and potential applications for these devices. In home entertainment, for example, digital equipment eliminates ghost images from television sets, and digital audio recorders produce unprecedented clarity and fidelity without the background hiss of analog systems. In robotics, pattern recognition implemented with specialized DSP techniques is already common, while speech recognition systems are being developed for operator control of industrial machinery. The evolving all-digital telephone system will enable simultaneous voice and high-speed data communications across long distances. And in the medical arena, DSP chips are applied in ultrasound imagery, which is often used to observe babies in the womb, and in CAT (computerized axial tomography) scanners that enable accurate diagnosis without the need for exploratory surgery; DSP-implemented speech recognition may someday lead to AI-based diagnostic systems that can query patients and recognize their verbal answers.

by William I. Strauss

Several major computer and telecommunications companies, including AT&T, IBM, and Texas Instruments, are involved in DSP technology. Among more moderately sized chip makers, three companies—Advanced Micro Devices (Sunnyvale, Cal.), Analog Devices (Norwood, Mass.), and Integrated Device Technology (Santa Clara, Cal.)—are in good positions to benefit from the spread of DSP.

Advanced Micro Devices (NYSE: AMD) was a pioneer in specialized microprocessor chips for board-level DSP circuits used in military and medical equipment. In 1985, AMD introduced a family of advanced 32-bit integrated circuits for very-high-performance DSP applications such as radar signal processing and graphics workstations. Earlier 4-bit versions of these chips encountered heavy competition from clones manufactured by LSI Logic and General Electric, among others, but the new 32-bit designs are sufficiently advanced to avoid this problem over the near future. New, highly automated plants in Austin and San Antonio should also enable the company to keep costs competitive.

Sales in 1985 were $931 million, with profits of $135 million and $2.32 earnings per share. AMD experienced its first loss in many years in fiscal 1986, coinciding with the recession in the semiconductor industry. Losses were $36.6 million, or 65¢ per share, based on sales of $576 million. Sales and earnings for fiscal 1987 are expected to be still lower as the semiconductor slump stretches out; but prospects should improve as recently introduced designs move into volume production.

Analog Devices (NYSE: ADI), a leader in chips that convert analog signals to digital form and vice versa, stands to profit regardless of whether analog or digital DSP chips are implemented by the user. The company, however, has also become directly involved in DSP markets by introducing two families of very fast microprocessors favored for DSP applications. One set of products employs building-block processor and math chips for military and other very-high-speed applications; the other product line consists of a single-chip DSP applied primarily in graphics workstations and other commercial uses. The company has also improved its long-term prospects by obtaining rights to certain technological developments by start-ups that received venture capital from Analog Devices Enterprises, a joint endeavor with Standard Oil of Indiana. Possibilities include new silicon fabrication processes, gallium arsenide integrated circuits, and new image processing technologies; any of these developments could lead to even faster DSP chips.

Revenues in 1985 were $322 million; profits were $29.7 million, earnings per share 65¢. Revenues in 1986 were marginally higher at $337 million, and earnings only slightly off at 54¢ per share, making Analog the most profitable major semiconductor house in the depressed market of 1986.

Integrated Device Technology (OTC: IDTI) specializes in producing high-speed circuits using a unique CMOS (complementary metal-oxide semiconductor) process that employs faster and higher-power transistors only at selected locations on the chip. These devices run faster than competitors' traditional CMOS devices and require less power than somewhat faster bipolar chips. Integrated Devices' fast-access CMOS static memory chips have been popular for high-reliability military applications, enabling the company to enjoy average selling prices well above those of most other IC houses. Recently, Integrated Device introduced clones of AMD's earlier family of 4-bit processors; these should also be popular with the military.

The company's fiscal 1985 earnings were $5.6 million, or 40¢ per share, based on sales of $38.4 million. Although 1986 sales increased to $57.7 million, earnings dropped to $3.2 million and 23¢ per share. □

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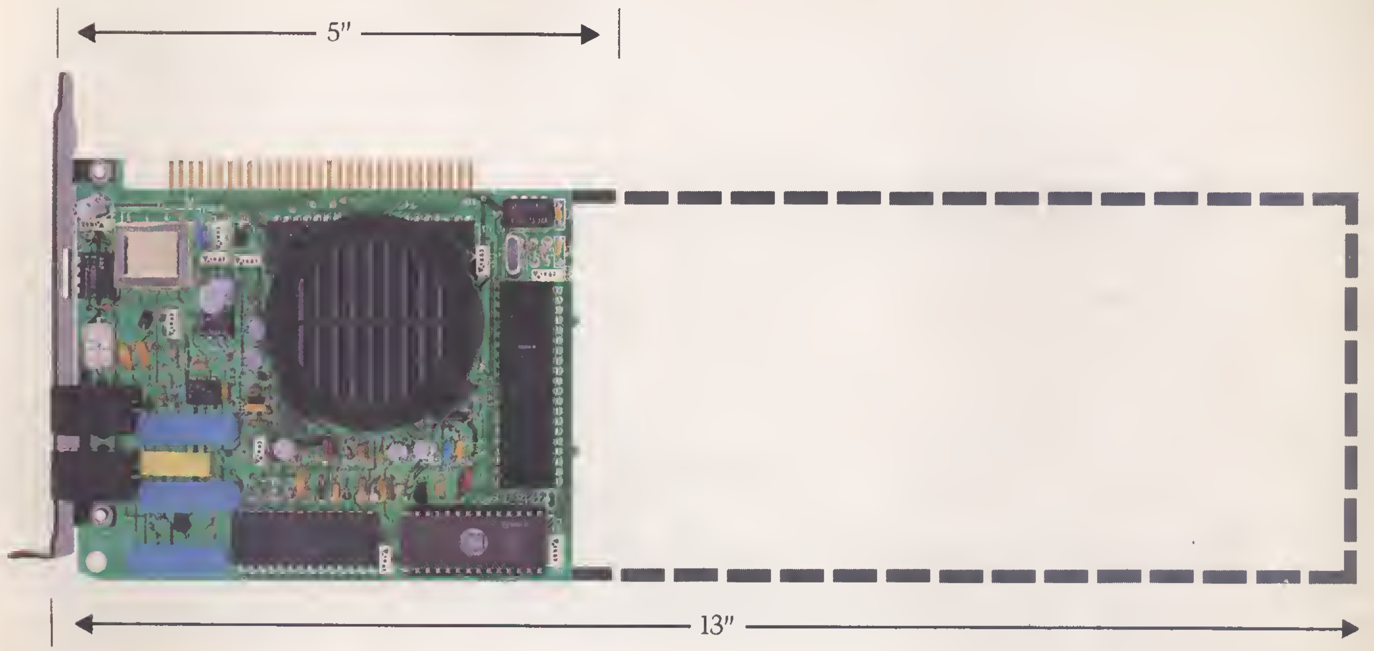

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